FINAL REPORT

FOR

HIGH RESOLUTION FOURIER TRANSFORM SPECTROMETER

MODEL 296

SERIAL NO. 091002

PREPARED FOR

NASA Manned Spacecraft Center
Space Sciences Procurement Branch
Houston, Texas 77058

Under

Contract No. NAS-9-9807

September 1971

Block Engineering, Inc.
CAMBRIDGE 39, MASSACHUSETTS

FINAL REPORT

INSTRUCTION MANUAL

OPERATION AND MAINTENANCE PROCEDURES
ELECTRONIC SCHEMATICS

MODEL 296

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INTRODUCTION

This manual describes a Michelson interferometer spectrometer which has been fabricated by Block Engineering, Inc.; Cambridge, Mass., for NASA Manned Spacecraft Center, Space Sciences Procurement Branch, Houston, Texas under contract No. NAS9-9807. The interferometer spectrometer is a modified Block Engineering Model 296 capable of 0.5 cm^{-1} resolution over the spectral region of 5-15 microns configured for operation with the optical head at a temperature of approximately 80°K. The spectrometer consists of two separable units: the electronic controller and the optical head. The electronics controller contains the main electronic components: low voltage power supplies and regulators for the amplifiers and logic circuitry, high voltage power supplies for the reference laser and piezo-electric crystal adjustable mirror mount, constant velocity servo system for the mechanical transducer, associated electronic components for signal processing and conditioning, and various pressure monitoring and regulating subsystems. The optical head which is cooled to ~80°K contains the Michelson interferometer and integral transducer and referencing system, the optical system, detector, cryogen storage compartments and pressure sense and regulation devices. The detector used is mercury doped germanium (Ge:Hg) at a temperature of ~4°K by means of liquid helium. Unique features of this instrument are the optical head operating temperature of 80°K, use of antireflection coated germanium as the beamsplitter and the use of the cryogen boiloff as the source of gas for the pneumatic transducer bearing.

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SPECIFICATIONS

Model 296/Cryogenic

Spectral Range	5-15 microns
Beamsplitter Construction	Germanium with multi-layer antireflection coatings
Detector	Ge:Hg @ $\sim$ 4°K
Resolution	4, 2, 1, 0.5 cm^{-1}
Wavelength Precision	0.1 cm^{-1}
Optical Retardation	0.25, 0.5, 1.0, 2.0 cm
Scan Velocity	1.26 cm/sec (Nominal)
Velocity Precision	Better than 10%
Scan Time	2 sec/scan for 2 cm scan
Duty Cycle	$\geq$ 80% for 2 cm scan
Available Sampling Interval	0.6328 microns x 1/2, 1, 2, 4, 8, 16
Limiting Aperture (Interferometer)	Two inch diameter
Field of View (Interferometer)	2.56° full angle
Limiting Aperture (Entrance)	0.72 inch diameter
Field of View (Entrance)	7.2° full angle
Optical Head Temperature	$\sim$ 80°K
Cryogen Hold Time	$\sim$ 8 hours
Optical Head Size	16 x 24 x 35
Optical Head Weight	$\sim$ 150 lbs.
Control Unit Size	9 x 16 x 19
Control Unit Weight	$\sim$ 20 lbs.
Power Consumption	200VA, 115V, 60Hz
System Fusing	3 AG, 3 amp
Detector Sensitivity Levels	1, 3, 10, 30, 100
Detector Output Levels	20 volts P-P

SECTION I

GENERAL

1.1 Equipment Supplied

The following equipment should be included in your shipment:

1. Interferometer Controller
2. Optical Head
3. Detector
4. Interconnecting cables and accessories

1.2 Inspection

Carefully examine the shipment for possible damage in transit. If any damage is observed, refer to the instructions below.

1.3 Claim for Damage in Shipping

The instrument should be visually inspected and tested for proper operation as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be made out and forwarded to Block Engineering, Inc. who will then advise you of the disposition of the equipment and arrange for repair or replacement. Include the model and serial numbers in any correspondence regarding this instrument.

1.4 Return for Repair Instructions

If any fault develops, the following steps should be taken:

1. Notify Block Engineering, Inc., giving full details of the difficulty; include model and serial numbers. Upon receipt of this information, Block Engineering, Inc., will reply with either service or shipping instructions. DO NOT return any equipment without prior acknowledged notification.

2. If the instrument is to be returned to Block Engineering, Inc., pack it in its original container or according to the shipping instructions, and forward it prepaid to the address given below. Unless otherwise instructed, arrange shipment via air freight. If the original shipping container has been discarded, the instrument should be packed in a strong exterior container (preferably wood) and surrounded by at least two inches of foam rubber or similar shock absorbing material.

3. Address shipping container as follows:

Block Engineering, Inc.
19 Blackstone Street
Cambridge, Massachusetts 02139

SECTION II

THEORY OF OPERATION

2.1 Ideal Interferometer

Figure Number One is a simplified optical diagram of a Michelson interferometer consisting of a fixed mirror (M_1), a moving mirror (M_2) and a beamsplitter (BS). For the purposes of this discussion, the following assumptions are made.

The beamsplitter is assumed to be ideal, i.e., the beamsplitter is lossless and divides any incident ray into a reflected and transmitted ray of equal amplitude. It is assumed that the beamsplitter is a dielectric material and that all angles between input/output rays and the normal to the beamsplitter surface are smaller than the polarizing angle. The mirrors are assumed to be metallic and lossless. The discussion will proceed by considering the transmitted beam in what is considered a normal configuration of the interferometer (i.e., source and detector are on opposite sides of the interferometer).

Ignoring all phase changes upon reflection consider a parallel bundle of monochromatic light of intensity I entering the interferometer at A and arriving at B having been divided by beamsplitter and traversing the two different arms of the interferometer.

The wavefront striking the beamsplitter from A can be characterized by the equation

$$\sqrt{I(t)} = \sqrt{I}\, e^{2\Pi j\omega t}$$

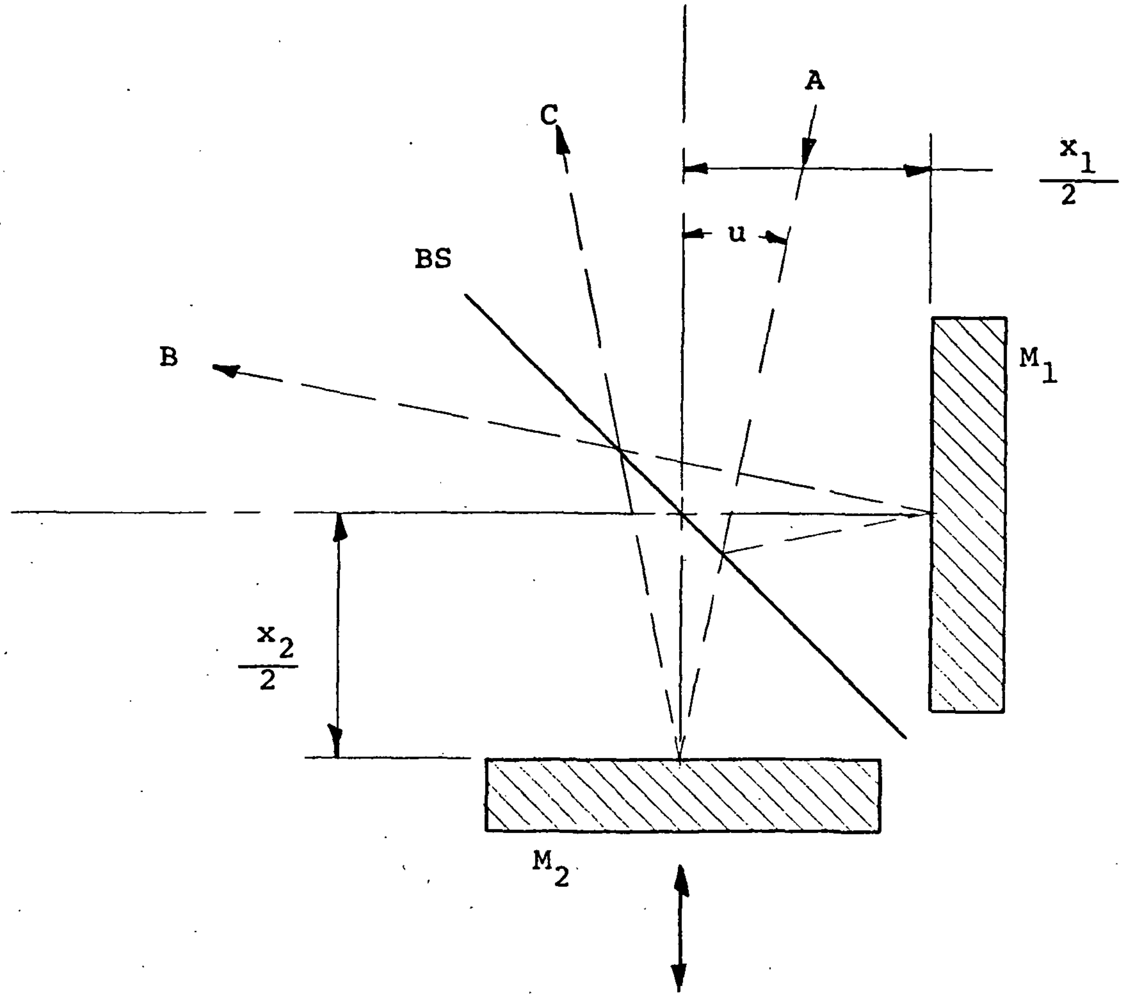


Figure Number One
Simplified Optical Diagram

Michelson Interferometer

M_1	Fixed Mirror	u	Obliquity Angle
M_2	Moving Mirror	I	Beam Intensity at A
BS	Beamsplitter	I_B	Beam Intensity at B
A	Input	I_C	Beam Intensity at C
B	Output	ν	Optical Frequency (cm^{-1})

ρ	Beamsplitter Reflection Coefficient
τ	Beamsplitter Transmission Coefficient
$x_1/2$	Beamsplitter to Mirror M_1 Distance (cm)
$x_2/2$	Beamsplitter to Mirror M_2 Distance (cm)

Thus the beams arriving at B from the arms containing M_1 and M_2 respectively are:

$$\sqrt{I \cdot \rho \cdot \tau}\ e^{2\Pi j(\omega t - x_1 \nu)}$$

and

$$\sqrt{I \cdot \rho \cdot \tau}\ e^{2\Pi j(\omega t - x_2 \nu)}$$

The sum at B can be expressed as

$$\sqrt{I_B}\ e^{2\Pi j \omega t} = \sqrt{I\rho\tau}\ [e^{2\Pi j(\omega t - x_1 \nu)} + e^{2\Pi j(\omega t - x_2 \nu)}]$$

The action of the detector has the effect of eliminating the time dependence of the above equation through the intermediate relationship

$$\sqrt{I_B} = \sqrt{I\rho\tau}\ [e^{-2\Pi j(x_1 \nu)} + e^{-2\Pi j(x_2 \nu)}]$$

which reduces to

$$I_B = I\rho\tau\ [2 + 2 \cos 2\Pi(x_2 - x_1)\nu]$$

when multiplied by the complex conjugate.

Under the assumption of an ideal beamsplitter where $\rho = \tau = 0.5$

$$I_B = 0.5I\ [1 + \cos 2\Pi(x_2 - x_1)\nu]$$

The quantity $x_2 - x_1$ is referred to as the optical retardation and is defined as B so that

$$I_B = 0.5I\ [1 + \cos 2\Pi B\nu] \qquad (1)$$

If the interferometer mirror is moved at constant velocity defined by B/T then the quantity I_B becomes

$$I_B(t) = 0.5I\ [1 + \cos \Pi 2 \frac{B\nu}{T} t] \qquad (2)$$

Thus for a monochromatic input, the intensity of the output at B will be the summation of a D.C. level corresponding to 0.5I and a cosinusoidally varying signal of amplitude 0.5I and frequency $\frac{B\nu}{T}$. Since the D.C. component contains no spectral information it is generally ignored. The A.C. portion of the signal contains both intensity and wavelength information so that is alone is necessary for recording of the spectrum. For the case of a monochromatic input the interferometer simply produces a sinusoidally varying output the amplitude of which is proportional to the intensity of the input and the frequency of which is inversely proportional to the wavelength. (Example: For a retardation velocity of 1.26 cm/sec., the output frequency for a 10μ input is simply (1.26 cm/sec.)/10^{-3} cm or 1260 Hz. Similarly a 5 micron input wavelength corresponds to a frequency of 2520 Hz at the detector.)

The radiation from a blackbody contains energy at all wavelengths in a large region of the spectrum and thus produces a signal in the interferometer which is the summation (integral) of as many sinusoids. This easily recognized signal is called an interferogram (or white light interferogram) and is shown in Figure Two, Typical White Light Interferogram.

By examining the equation describing the performance of an interferometer for a monochromatic source a number of conclusions can be drawn concerning the interferogram produced by a source of finite wavelength extent in an ideal case. The interferogram is symmetric about B equal to zero. The center peak in the interferogram occurs at zero retardation and is caused by the fact that at zero retardation all components have the same phase. The peak amplitude of the interferogram is proportional to the total energy in the incident radiation that is modulated by the interferometer.

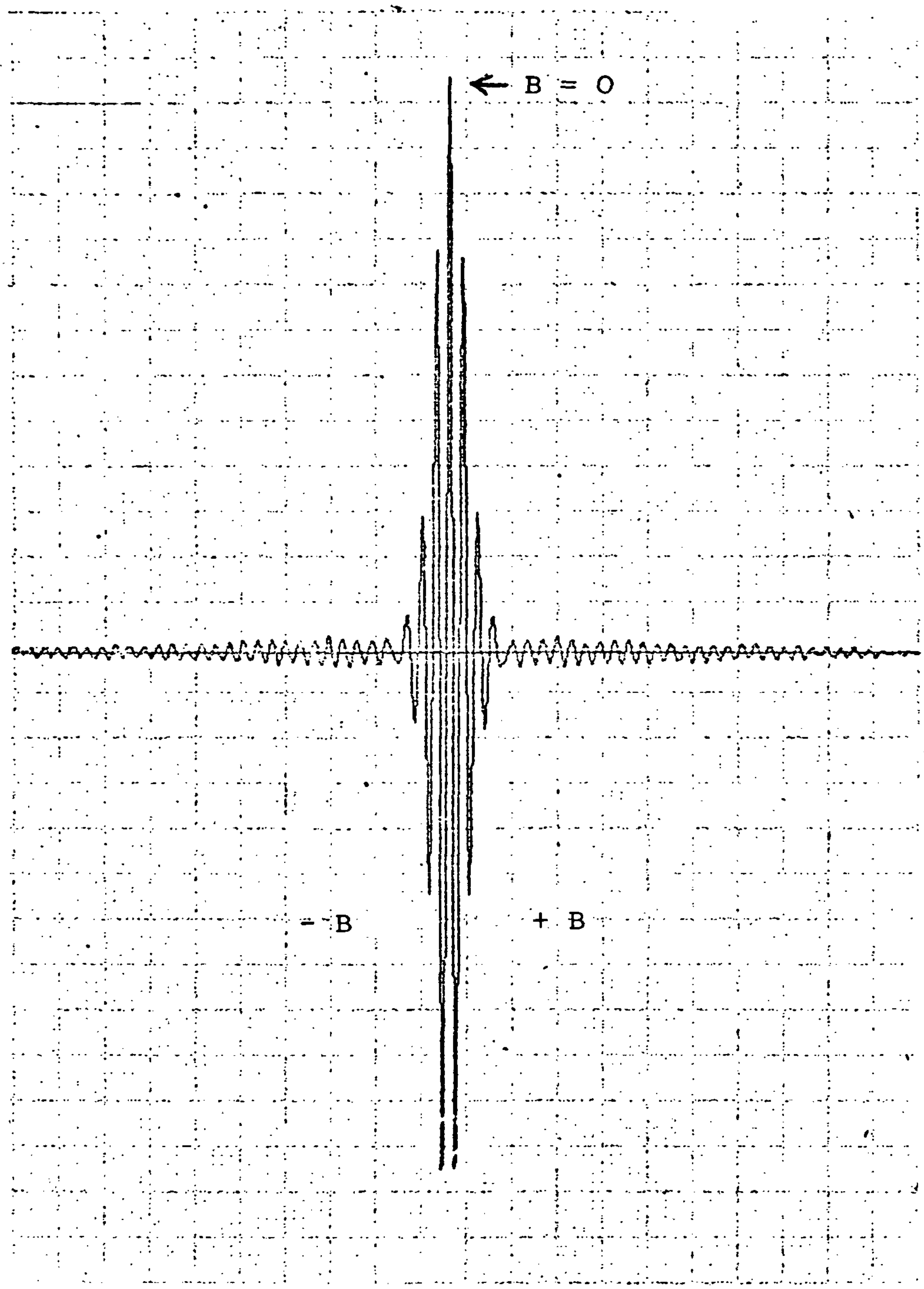


Figure Number Two
Typical White Light Interferogram

2.2 Non-Ideal Interferometer

The non-ideal interferometer (in this discussion) is defined simply as one which introduces wavelength dependent phase differences into the transmitted signals. This can be described mathematically by slightly modifying equation number (1) to

$$I_B = 0.5I \left[1 + \cos\left(2\Pi \frac{B\nu}{T} t + \phi_\nu\right)\right] \qquad (3)$$

where ϕ_ν = the wavelength dependent phase shift. These phase shifts may be a result of a number of things such as phase changes at reflection and incomplete compensation in the beamsplitter and compensation assembly. Figure Number Three describes such an interferogram. A number of points should be noted for this case. The interferogram is no longer symmetric about B equal to zero. Due to the phase angle each wavelength undergoes zero retardation at slightly different positions of the moving mirror M_2. The peak amplitude is now only approximately proportional to the total energy in the incident radiation that is modulated by the interferometer.

2.3 Complimentarity of Outputs/Ideal Interferometer

In the discussion of an ideal interferometer (Section 2.1) only the case of the transmitted output (energy arriving at B from A) was considered. Clearly, energy is also reflected by the interferometer and arrives at C from A. The analysis in Section 2.1 ignored all phase shifts caused by the system so that in this regard both the output at B and the output at C can be described by equation (1). However, for the lossless system as outlined a contradiction quickly becomes apparent, i.e. for B = 0,

$$I_B = I$$
$$I_C = I$$

and

$$I_B + I_C = 2I.$$

This clearly violates the conservation of energy and the obvious conclusion is that for the system described phase shifts cannot be ignored.

Figure Number Four describes the phase shift caused by reflection from a dielectric (S polarized light being perpendicular to the plane of incidence and P polarized light being parallel to the plane of incidence). Since the interferometer works the metal mirrors (M_1 and M_2) at or near normal incidence the phase change for any polarization direction is Π. However, with a dielectric beamsplitter the phase change will not be the same for the two polarizations. Energy which is S polarized will undergo a phase change of π at the beamsplitter while energy which is p polarized will undergo no phase change for angles of incidence less than the polarizing angle. (Two typical examples of dielectric beamsplitters are those which are deposited on a substrate such as Fe_2O_3 on CaF_2, and those which use the Fresnel reflection characteristic of the material to split the beam such as Ge.) The polarization angle $\overline{\phi}$ is related to the index n of a material by the relation $\tan \overline{\phi} = n$. For Fe_2O_3 the index is approximately 3 and the polarization angle is approximately 72°. For germanium the index is approximately 4 and the polarization angle is approximately 76°. Since the interferometer generally works within a few dgrees of the optical axis, say at 45° $\pm$ 10° to the plane of the beamsplitter, the angle of incidence will always be less than the polarizing angle and the phase change for the above mentioned materials will in all cases be zero for p polarized light.

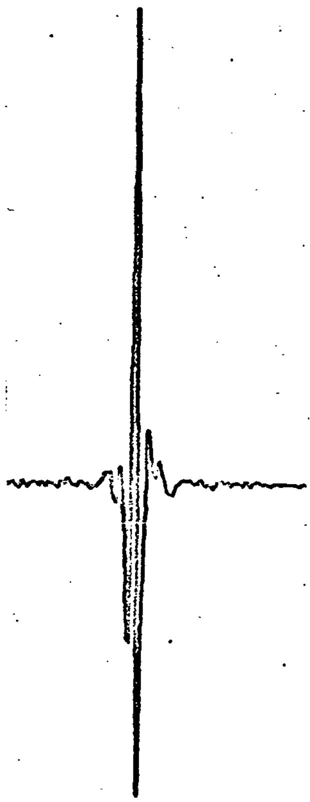


Figure Number Three
White Light Interferogram With
Wavelength Dependent Zero Phase

Therefore, for the case of the two materials mentioned above, the relative phase of the polarizations are easily determined and are summarized below by tracing rays through the interferometer in Figure Number One and referring to Figure Number Four for the phase changes at the beamsplitter.

Energy which is _______polarized	S	P
and arrives at B from A via arm		
containing ____________ will	M_1	M_2
undergo a phase change (by reflection)		
of ____at the beamsplitter	Π	o
of ______at the mirror	Π	Π
and of ______at the beamsplitter	o	o
for a total phase change of	2Π	Π

Energy which is _______polarized	S	P
and arrives at C from A		
via arm containing _____will	M_1	M_2
undergo a phase change (by reflection)		
of ______at the beamsplitter	Π	o
of ______at the minor and	Π	Π
of ______at the beamsplitter	Π	o
for a total phase change of	3Π	Π

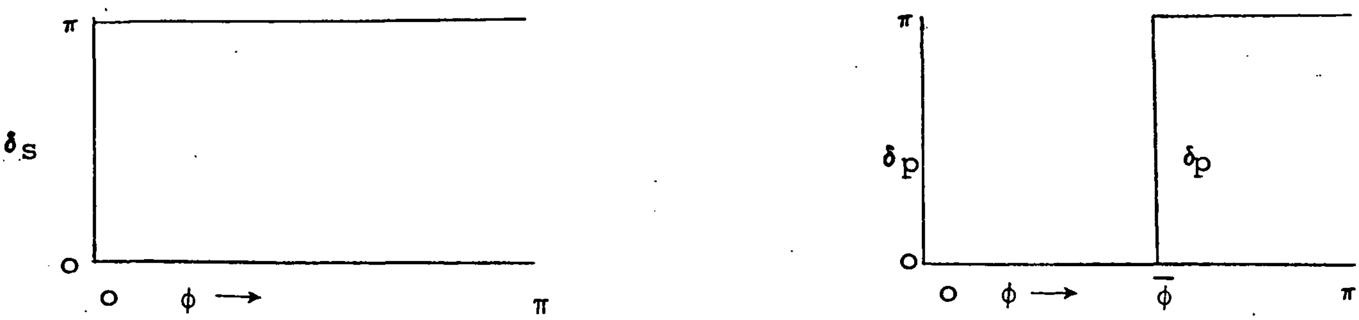
Note that the S and P polarization at B are out of phase by Π and that the S and P polarization at C are in phase. Thus, the interferograms at B and C respectively are given by

$$I_B = 051 \left[1 + \cos.\ (2\pi \frac{E\nu}{T} t + \pi)\right]$$

and

$$I_C = 0.51 \left[1 + \cos.\ (2\pi \frac{B\nu}{T} t)\right]$$

With the above equations conservation of energy is no longer violated for case B = 0 which yields $I_B = 0$ and $I_C = 1$.



ϕ Angle of Incidence

$\bar{\phi}$ Polarizing Angle

δ_s Phase Shift for S Polarized Light

δ_p Phase Shift for P Polarized Light

Figure Number Four

Phase Shifts Due to Reflection From A Dielectric

Thus for an interferometer with a dielectric beamsplitter the white light signal in transmission is 180° out of phase with the white light in reflection (or alternately a black fringe by transmission and a white fringe by reflection). These complementary outputs form the basis of optical subtract and also give rise to such phenomena as "negative" spectral features.

2.4 Complimentarity: Consequences and Applications

Section 2.3 has discussed the complimentarity of outputs as to their origin. However, it remains to be discussed the consequences of this phenomenon as it may appear operationally and the possible applications of this phenomenon.

The most common manifestation of the complimentarity of outputs is the production of "negative" outputs from the spectrometer. ("Negative" is meant to imply that the modulated signal is 180° out of phase from what one would normally expect.) Although perfectly logical for a situation in which a detector at a given temperature views a target at a lower temperature (i.e. the net transfer of energy is to the lower temperature source) negative outputs from a detector operating at 5°K are not easily explained except in the rare case of a target being at a temperature less than 5°K.

In general, there are three sources of modulated energy viewed by the detector in a given measurement situation: the target, the target background, and the spectrometer itself. The modulated power on the detector is thus expressed by the sum

$$P_D = P_T + P_B + P_S \tag{4}$$

where

P_D = modulated power on the detector (watts),

P_T = modulated power on the detector from the target (watts)

P_B = modulated power on the detector from the target background (watts), and

P_S = modulated power on the detector from the spectrometer (watts).

If the assumption is made that the three sources are all at a temperature greater than 5°K then the net flux in all cases will be positive. However, as described in Section 2.3, in an interferometer with a dielectric beamsplitter a source warmer than the detector (e.g. an 80°K surface) located on the detector side of the beamsplitter will be modulated with a phase opposite that of energy coming from the opposite side of the beamsplitter. Provided that this energy eventually arrives at the detector its opposite phase will give it the appearance of energy leaving the detector, which is not at all the case. In the spectrum, this same phenomenon will manifest itself as a reduction of the output or in the case where $|P_S| > |P_T + P_B|$ the opposite phase of P_S will dominate and P_D will appear with a negative phase.

Since P_S is a constant term for a given operational configuration equation (4) may be rewritten as

$$P_D = P_T + P_B' \tag{5}$$

where

$$P_B' = P_B + P_S.$$

Thus P_S can be considered as part of the background and that one can obtain P_T through the relation

$$P_T = P_D - P_B' \tag{6}$$

Although not applicable to the instrument being described it is instructive to consider the technique of optical subtraction. By optical subtraction it is meant that one combines the transmitted and reflected outputs of an interferometer with a dielectric beamsplitter thereby subtracting the two outputs. This is shown diagramatically in Figure Number Five, and is accomplished by ignoring the D.C. component of the interferogram as given by equation (2). For B = O the energy arriving at D as a result of I_1 in reflection is

$$I_1\rho^2 + I_1 \tau^2 = I_1 (\rho^2 + \tau^2)$$

Again for B = O the energy arriving at D as a result of I_2 by transmission is

$$I_2 \rho\tau + I_2 \rho\tau = 2I_2 \rho\tau$$

Since the energy by transmission is out of phase by Π with the energy by reflection, the modulated energy arriving at the detector is

$$I_D = I_1 (\rho^2 + \tau^2) - 2I_2 \rho\tau$$

which, under the assumption that $\rho = \tau = 0.5$, reduces to

$$I_D = 0.5 (I_1 - I_2) \qquad (7)$$

The practical significance of the above is that for the case of large background signals and relatively faint targets the dynamic range of the system is reduced and the background is subtracted from a target.

Example: Consider the case of a target of intensity I_T in a background of intensity I_B.

$$I_1 = I_T + I_B$$

$$I_2 = I_B$$

and $I_D = 0.5 (I_T + I_B - I_B) = 0.5 I_T$.

so that for an ideal interferometer the background is totally subtracted.

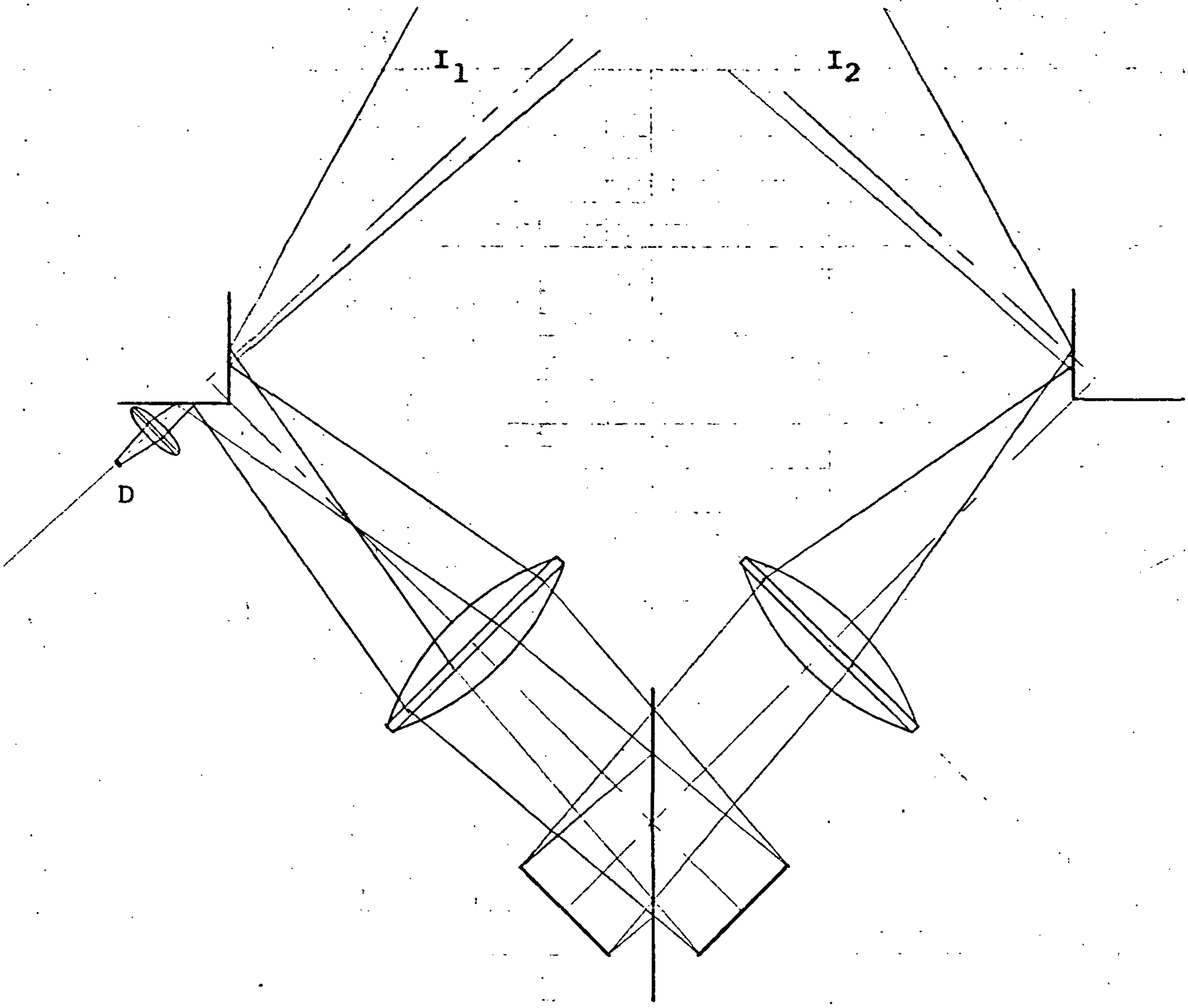


Figure Number Five

Optical Subtract Implementation

2.5 Resolution and Obliquity Limit

As previously noted the argument of the cosine in equation (1) expresses the output frequency f_ν as a function of wavenumber according to the relation

$$f_\nu = \frac{B}{T} \cdot \nu$$

where

$$\nu = \frac{1}{\lambda} ,$$

This statement expresses the fact that the interferometer translates the frequencies of the electromagnetic radiation into an electrical signal at audio frequencies by a constant factor preserving the relative frequencies. The recovery of the spectral information is obtained by performing a Fourier transform on the interferogram which may be thought of as a simple harmonic analysis of the interferogram. For a monochromatic source the output of the interferometer with a finite optical retardation B will be a sine wave of a finite number of cycles. The Fourier transform of this function yields the familiar sync function line profile whose half width is determined by the total length of the sine wave. In lieu of a complicated mathematical determination of the width of the line profile as a function of B, it is instructive to consider the following case. Let us say that two monochromatic sources of slightly different frequency (ν and $\nu + \Delta\nu$) would be resolved if over the length of the interferogram (B) there is a difference of one cycle in the total number of cycles N produced by the two lines, i.e.

$$B\nu = N + 1 \text{ and } B(\nu + \Delta\nu) = N$$

Equating the above

$$B\nu + 1 = B\nu + B\Delta\nu$$

or

$$\Delta\nu = \frac{1}{B} \tag{8}$$

which simply states that the resolution of the interferometer spectrometer is constant in wavenumbers throughout the spectrum and is inversely proportional to the retardation B.

It must be noted, however, that the above equation is valid only for the axial case, i.e. the obliquity angle $u = 0$. For the case of a finite obliquity angle ($u > 0$) the resolution will be somewhat reduced. This results since retardation produced by the interferometer is a function of the angle at which a ray traverses the system. The retardation produced by a finite angle is given by the relation

$$B(u) = B(o) \cos u$$

where $B(o)$ is the on axis retardation.

The maximum allowable obliquity in a system is a function of both the shortest wavelength of interest (λ) as well as the retardation (B) and is described by the equation

$$u^2 = \frac{1}{B\nu} = \frac{\lambda}{B} \tag{9}$$

When the field-of-view is restricted to the half-angle described by equation (9) the effect on the interferogram at the shorter wavelengths is that of a cosinusoidal apodization which increases slightly the instrument profile and reduces its sidelobes.

SECTION III

INSTRUMENT DESCRIPTION

3.1 Basic Interferometer

Figure Number Six is a pictorial representation of the interferometer optical head showing the major optical components thereof. Basically it can be divided into three main sub-assemblies: the signal (or main) interferometer, the bearing and transducer assembly, and the reference interferometer; and three secondary areas: pressure regulation and bearing feed, window assembly and dewar modifications.

3.1.1 Signal or Main Interferometer

The signal interferometer is of conventional Michelson design. The beamsplitter/compensator substrates are germanium flats manufactured to the appropriate tolerances. The beamsplitting capability utilizes the Fresnel reflection from this high index (n=4) material. Secondary reflections from the additional surfaces are suppressed using a multi-layer anti-reflection coating on three of the four surfaces. The moving mirror has been fabricated from 6061-T6 aluminum and is provided with integral mounting points for attachment to the transducer. The adjustable mirror is a first surface aluminized quartz flat. The mirrors have been provided with a clear aperture of 2.25 inches. The adjustment mechanism for the adjustable mirror is a combination of a mechanical system for rough aligning coupled with a piezo-electric support for remote and fine adjustment.

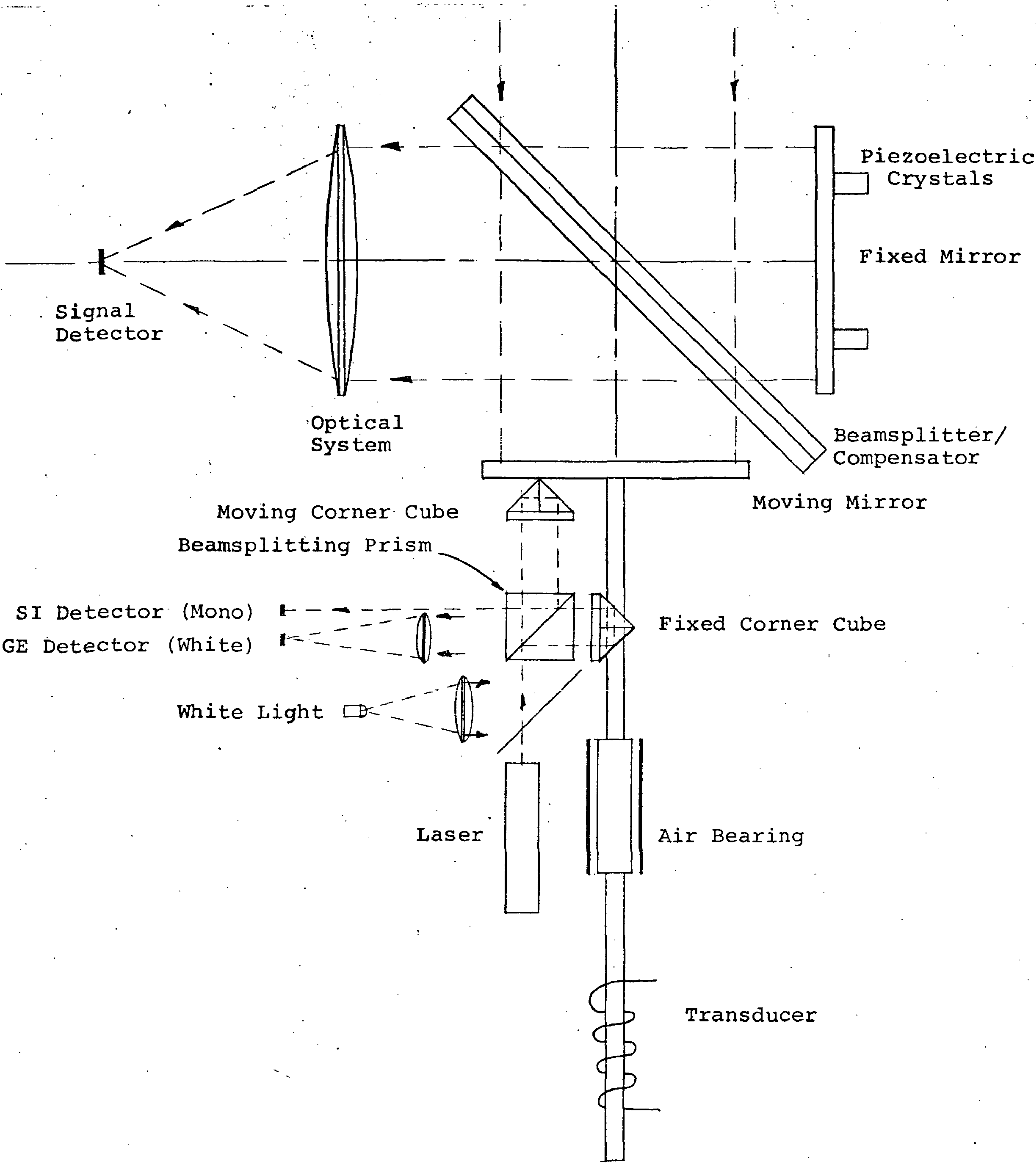


Figure Number Six
Signal and Reference Interferometer

3.1.2 Bearing and Transducer Assembly

Scanning of the interferometer is accomplished by moving the signal interferometer mirror with a permanent magnet and coil assembly similar to that commonly found in a loudspeaker. This moving assembly is supported by a cylindrical air bearing manufactured to tolerances such that the tilt of the moving mirror is held to within predetermined specifications commensurate with the wavelengths and resolution at which the system is operated. The air supply for the bearing is GN2 which is produced by the boiloff of the LN2 cryogen.

3.1.3 Reference Interferometer Assembly

The most complex of the three major sub-assemblies within the optical head is the reference interferometer. This system serves two functions: first, it provides a reference signal for the constant velocity servo and the sampling channel and second, it provides an absolute position reference or fiducial to enable coherent addition of successive interferograms. This assembly is a corner cube interferometer which has been implemented to eliminate the need for remote adjustment of the reference interferometer. This capability is provided by the tilt compensation which is an inherent quality of the corner cube interferometer. One corner cube is mounted on the back side of the moving mirror, the second corner cube is mounted on a fixed support assembly which also holds a beamsplitting prism to complete the interferometer. A monochromatic source (i.e. a He-Ne laser at 0.6328 microns) is used to generate a sinusoidal output from a Si cell as the moving mirror scans. The frequency of this signal is directly proportional to the velocity of the transducer and each cycle indicates a change in the retardation of 0.6328 microns. The white light interferogram generated by the tungsten lamp and the Ge detector gives absolute positional information and serves as a starting point for the determination of the scan length.

3.1.4 Typical Waveforms

Figure Number Seven indicates the typical waveforms which are generated by this instrument. The reference white light and monochromatic signals are combined to form the sync signal.

3.1.5 Bearing Feed and Regulator System

Figure Number Eight describes the bearing feed and pressure regulator system. This system has a number of functions the most fundamental of which is to supply gaseous N_2 to the air bearing. Secondary functions include: providing gaseous N_2 to eliminate frost buildup on the window assembly, control of the internal gas pressure by means of controlled applications of heat, and various safety overrides, reliefs as well as filling and quick dump valves.

The flow of nitrogen (both liquid and gas) is rather straightforward. The LN2 is loaded in the outer tank with the boiloff being collected and passed through an in-line filter. The pressure at this point is monitored by a gauge and regulated by the action of a pressure switch which controls the on-off cycling of a cartridge type immersion heater through the faceplate. The GN2 is then recooled by immersing the tubing in the LN2 and then used to cool the faceplate area of the detector dewar. It then proceeds to the bearing and vents

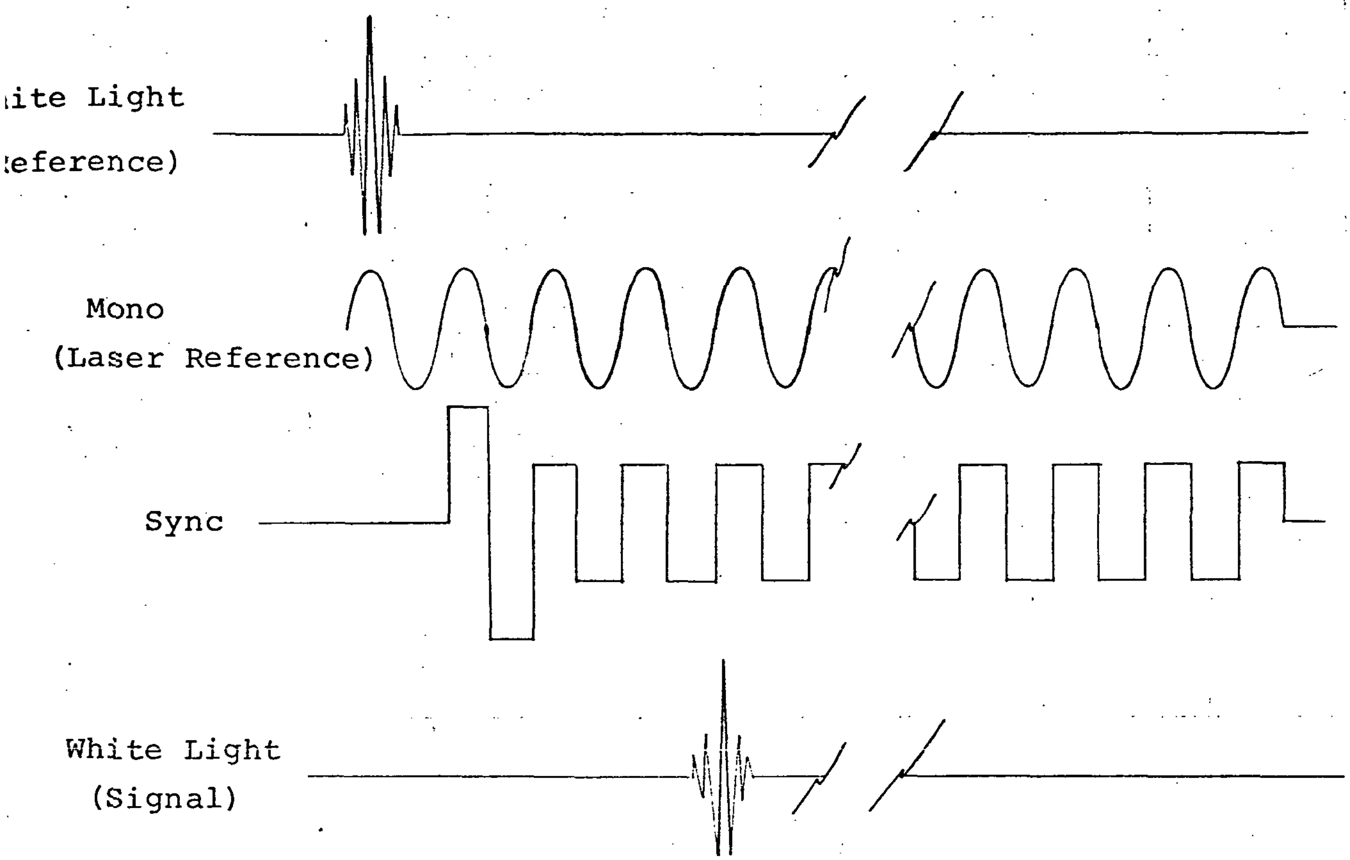


Figure Number Seven

Typical Waveforms

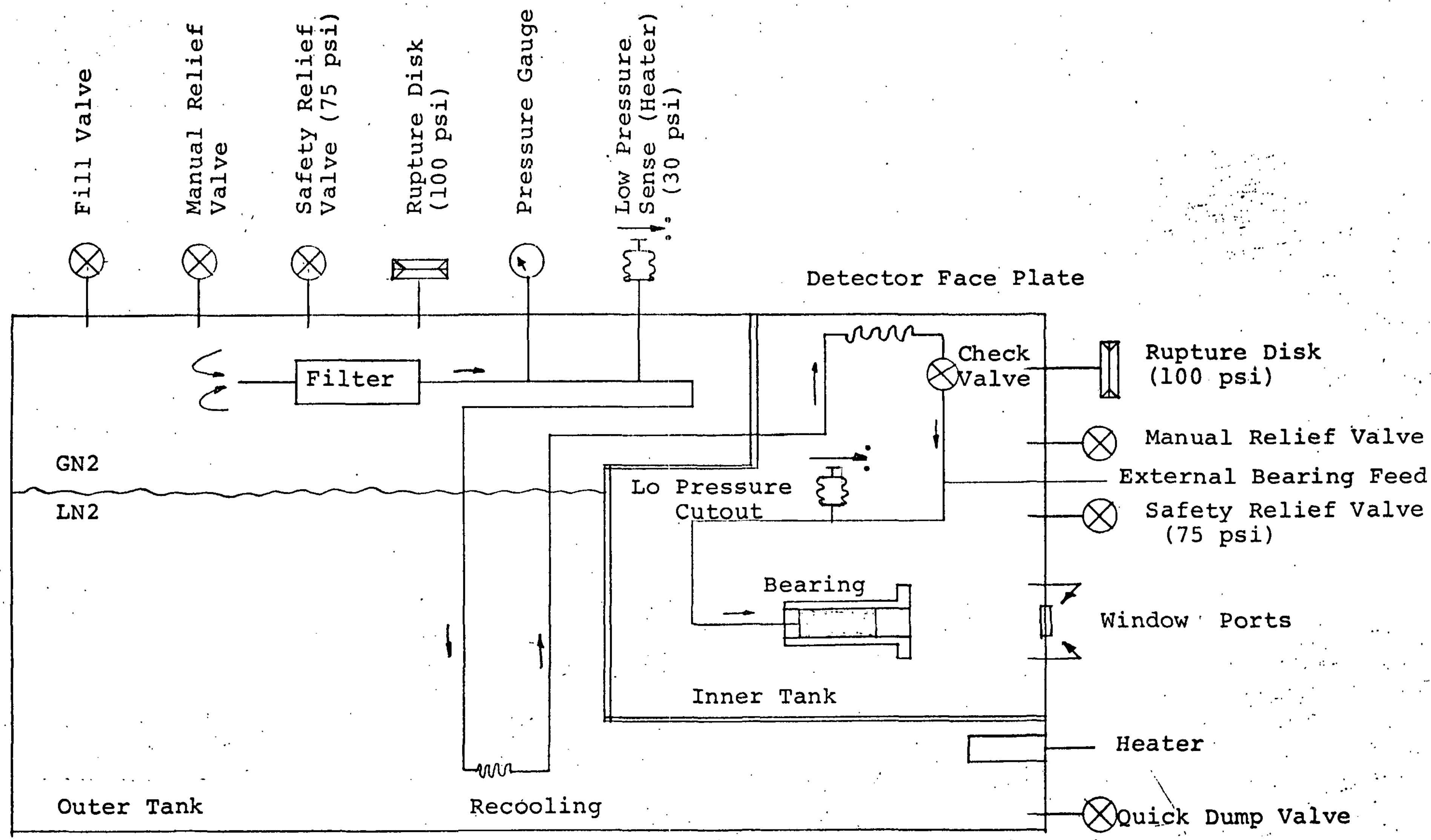


Figure Number Eight

Bearing Feed and Pressure Regulator System to the inner tank. A low pressure switch at the input of the bearing is used to shut down the entire instrument if the pressure is not at a preset value. The GN2 exits from the system through either the window ports or the manual relief valve. An auxiliary input to the air bearing is provided through the faceplate of the instrument. By pressuring the bearing from this point a check valve is closed so that the bearing is supplied via an external nitrogen source. The front plate of the instrument also contains a rupture disk, safety relief valve and manual relief valve for the inner chamber as well as a quick dump valve for the outer chamber.

3.1.6 Window Assembly

The window of the instrument is a germanium lens, the first element of the optical system. The assembly surrounding this element has been specifically designed for two modes of operation: in conjunction with an evacuated simulation chamber and in an "open window" configuration. This assembly is shown in Figure Number Nine

For operation in conjunction with the gas simulation chamber the four valves shown in Figure Nine are closed, the manual relief valve (to the inner chamber) is opened and the flanged end of the assembly is mated to the simulation cell.

For operation in an "open-window" configuration the manual relief valve is closed, the window valves are opened and a heated snout is attached to the window flange. Blowing GN2 on the window keeps it cold and frost free and the heated snout brings the GN2 to room temperature as it exits to ambient.

3.1.7 Dewar Modification

The detector dewar is a Santa Barbara Research Center Model 9145-STD dewar which has been modified for this application. The modifications include replacement of the standard

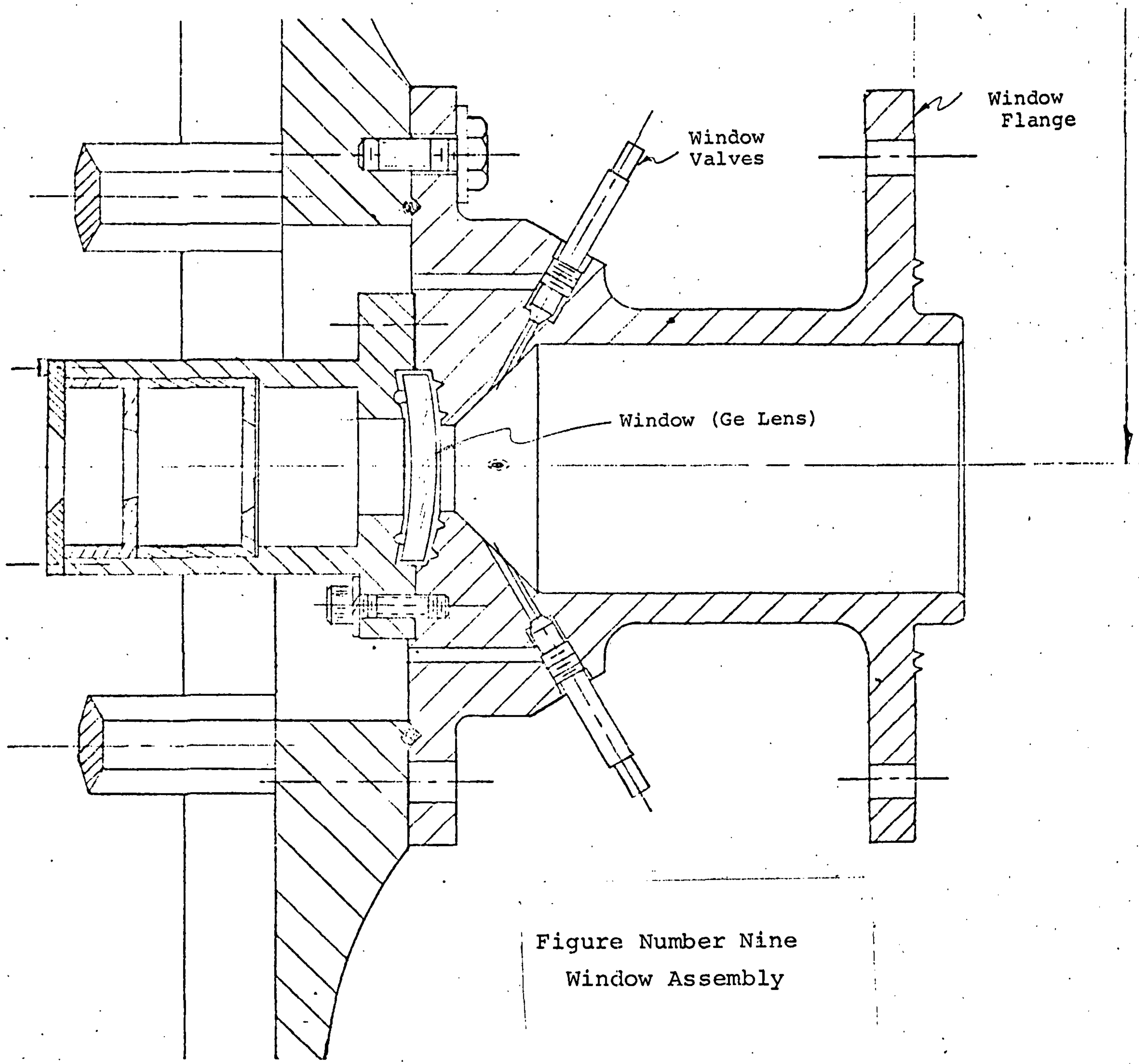


Figure Number Nine
Window Assembly

window with the germanium field lens, placement of the preamp load resistor on the cold finger, placement of the FET (which is the first stage of the preamplifier) on the radiation shield, and placement of a Ga:As LED on the detector cold shield.

3.2 Optical System

Figure Number Ten depicts the optical system used in the subject instrument. The objective lens focuses the field on the field stop which is coincident with the focus of the input Cassegrain which renders the radiation parallel upon entering the interferometer. The exit Cassegrain again focuses the field whereupon the energy proceeds to the field lens and the detector.

Figure Number Eleven depicts the optical system in a "line of sight" configuration and contains a table listing pertinent system design numbers and dimensional relationship. The entrance pupil of the system is the entrance lens clear aperture, the exit pupil is the detector and the fixed mirror of the interferometer is an intermediate pupil. The full field angle on the entrance aperture is 7.2°, in the interferometer 2.56° and at the detector 30°. The f/No. at the aperture of the instrument is f/8, of the entrance and exit Cassegrains f/4, in the interferometer f/22, and at the detector f/2. The throughput match for the system is 1 cm^{-1} resolution at 5 microns.

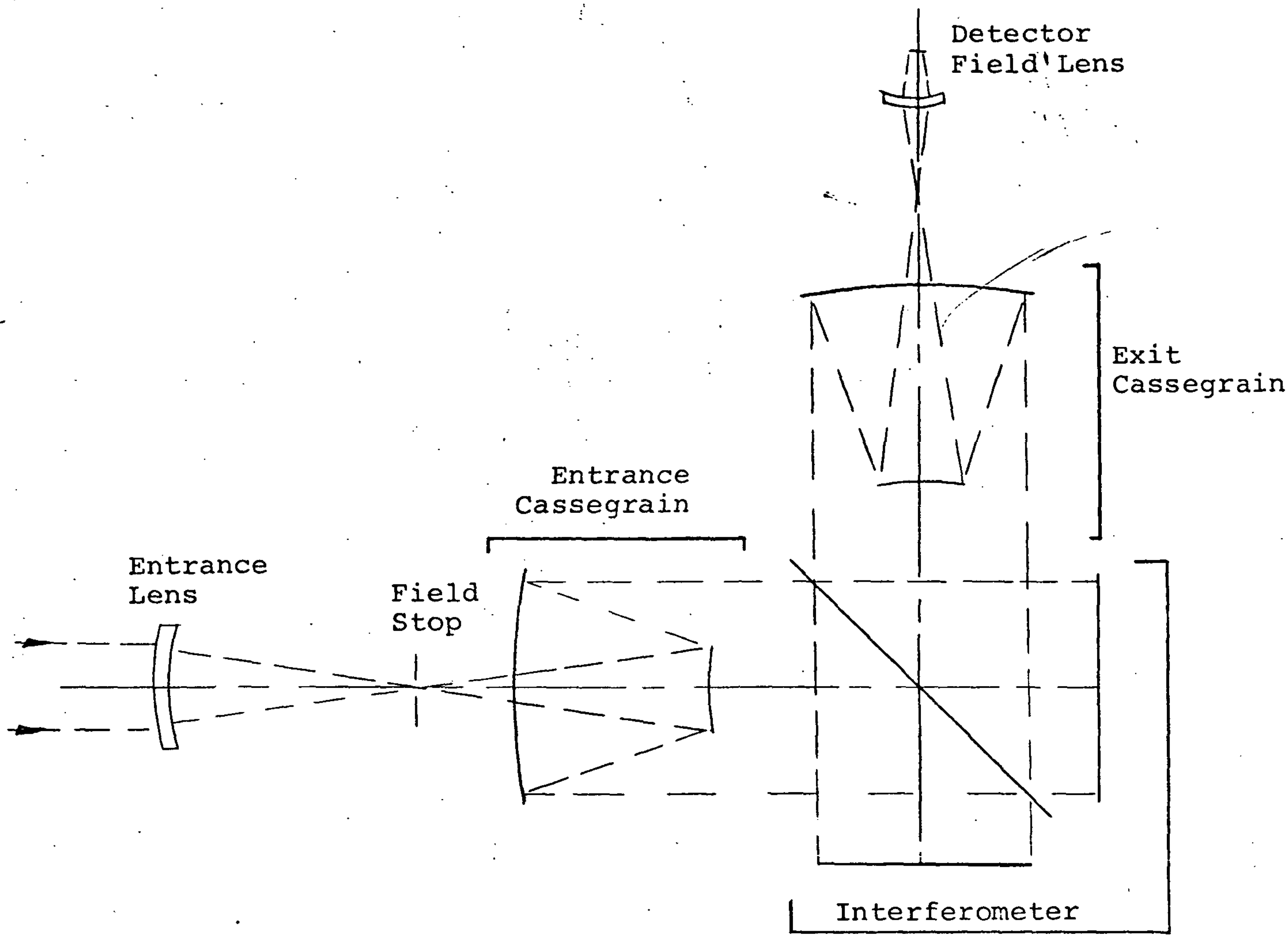


Figure Number Ten

Optical System Layout

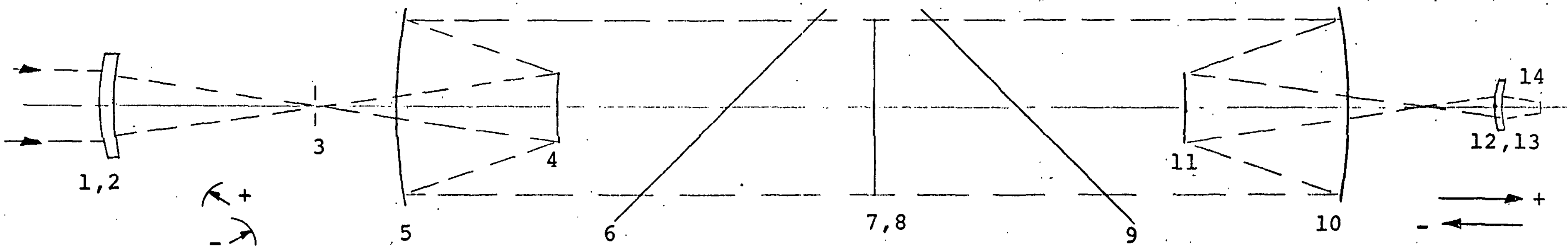


Figure Number Eleven - Optical System Parameters

Element	Surface Number	Radius of Curvature	Clear Apert. Diameter	Distance to Next Surface	Material	Applicable Block Drawing
Entrance Lens	1 2	2.878 4.0714	0.720 0.720	0.200 2.753	GE	622217
Field Stop	3	Inf.	0.180	3.306	---	
Cass. Secondary	4	5.961	0.980	-2.226	6061-T6	622218
Cass. Primary	5	7.587	2.600	6.561	6061-T6	631333
Beamsplitter/Compensator Moving Mirror Fixed Mirror Beamsplitter/Compensator	6 7 8 9	Inf. Inf. Inf. Inf.	----- 2.250 2.250 -----	6.561	GE 6061-T6 Quartz GE	
Cass. Primary	10	-7.587	2.600	-2.226	6061-T6	631333
Cass. Secondary	11	-5.961	0.980	4.305	6061-T6	622218
Field Lens	12 13	0.948 1.335	1.400 1.400	0.200 1.012	GE	622219
Detector	14	Inf.	0.200	-----	GE:Hg	------

NOTE: All dimensions in inches.

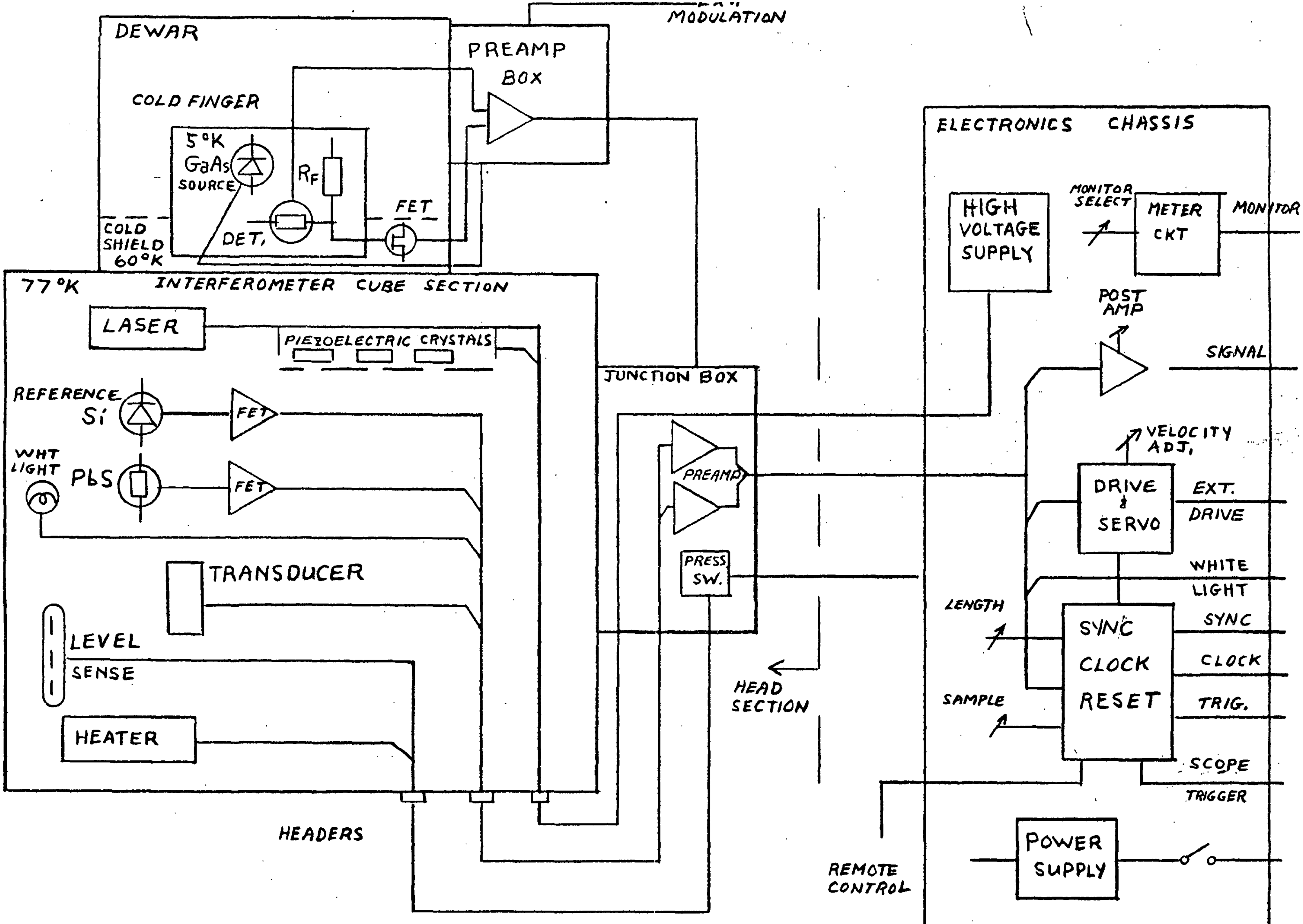
3.3 Electronic Circuits

Figure Number Twelve is a reduced version of Block Engineering, Inc. schematic drawing number E-920-22. Its purpose is to give the first time reader of the electronics description a sound footing before attempting to master all the specific details. The electronic circuits can be divided into five groups: the reference and synchronization circuits, the constant velocity servo and drive, the signal channel, power supplies, and the auxiliary circuits.

3.3.1 Reference and Synchronization Circuits

The reference section has silicon (mono) and germanium (white) photo-diode detectors. The silicon detector collects the He-Ne laser energy transmitted through the reference side of the cube. The monochromatic phase coherent laser energy serves two purposes. First, it gives an absolute velocity error signal that is used to maintain constant scan velocity. Second, any error in the scan velocity is phase coherent with the signal side of the cube, therefore, self correcting. The output of the monochromatic reference pre-amplifier goes through a Schmitt trigger which detects the zero crossings and generates a square wave. A digital frequency doubler generates a train of pulses whose average area is proportional to the frequency of the monochromatic interferogram and provides the velocity information to the servo loop.

The germanium detector collects all the energy radiated from a miniature filament type lamp. Since there is only one position in the scan where all the energy is phase coherent, it gives absolute positional information. The white light positional information serves the following purpose. It resets all the digital counters enabling data collection to



CRYOGENIC INTERFEROMETER BLOCK DIAGRAM

FIGURE 12

begin at the same position in the scan with the required optical resolution.

The output of the white light pre-amplifier goes through a peak detector which determines the point of zero retardation in the reference interferometer. This point is the start of the "Sync" signal. The Sync signal is a square wave whose period can be selected to be 1/2, 1, 2, 4, 8 and 16 times the period of the monochromatic interferogram and which is gated "on" by the white light peak detector signal, and is gated "off" at the end of each active scan. The first cycle of the sync signal is made 6 volts peak-to-peak and the rest is 2 volts peak-to-peak, to simplify the hardware in the data processing system. The "Trigger" and "Clock" signals provide the same information as the Sync signal through separate outputs (see figure number 13).

The end of scan is determined by a preset binary counter that starts with a "Sync" signal and counts fringes of the monochromatic interferogram. Retardation settings R1, R2, R3 and R4 determine the counters preset number. When the counter reaches the preset number, the active scan ends, the Sync and Clock signals are truned off and the moving mirror flies back to start another scan. A threshold detector on the "position" signal is activated if the counter fails to reach the preset number, and it starts the fly back.

3.3.2 Constant Velocity Servo and Drive

The constant velocity servo obtains its error information from the digital frequency doubler, which in this sense is used as a frequency to voltage converter. The doubled frequency pulses go through a level amplifier which normalizes

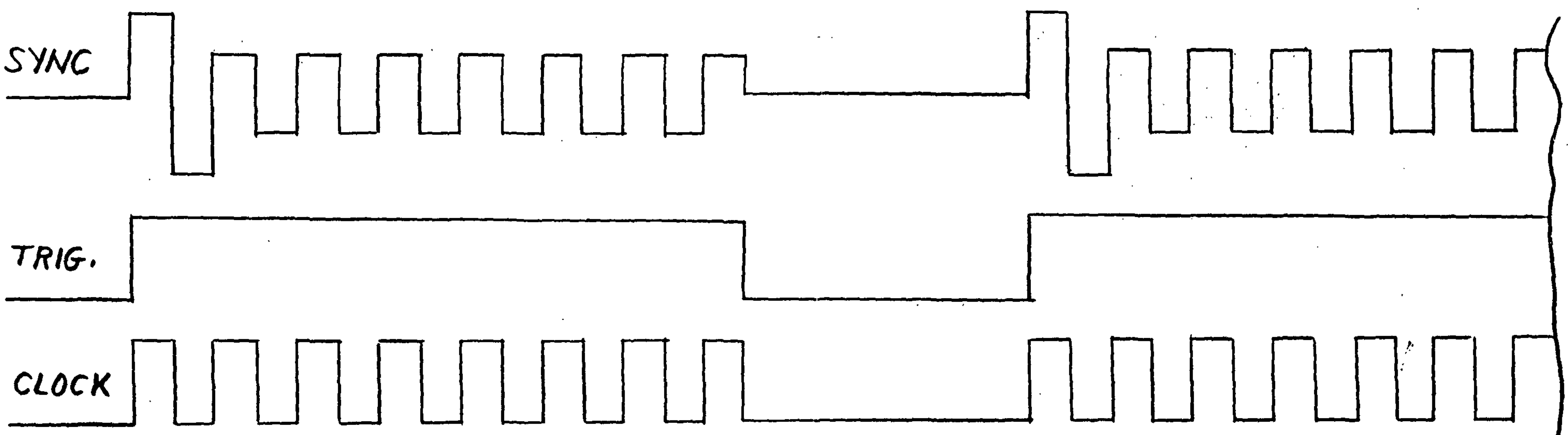


FIGURE NUMBER THIRTEEN

TIME RELATIONSHIP OF SAMPLING SIGNALS

the pulse amplitude and refers the error to 0 volts. This signal goes through a low pass filter and becomes the velocity feedback. The error signal is integrated with an operational amplifier to provide positional feedback.

The drive amplifier sums these error signals and provides a voltage to the transducer proportional to their sum.

During the flyback, a "Reset" signal removes the velocity and position error signals and applies a voltage which produces the flyback. A laser monitor circuit is activated when the laser beam does not reach the monochromatic detector and it turns the "Reset" signal on and disconnects the transducer drive.

A switch in the drive amplifier circuit card disconnects the constant velocity servo and allows manual and external control of the transducer drive. This feature is used to align both the reference and the signal interferometers.

3.3.3 Signal Channel

The signal channel consists of a pre-amplifier and post-amplifier mounted respectively at the detector dewar and electronic console. The preamplifier is an FET input operational amplifier specifically designed for low noise cryogenic front end operation. Hence, the dewar cold finger supports the detector, feedback resistor and GaAs source. The field effect transistor is mounted on the dewar's radiation shield to minimize operational amplifier input noise voltage.

The GaAs source serves the following two purposes. First, it enables the operator to check the pre-amplifiers frequency response by modulating the GaAs source via a BNC connector. Second, optimization of detector response time is achieved by adjusting a small d.c. bias on the GaAs source.

The pre-amplifier output signal is presented to the rear panel of the console and to the input of the post amplifier. The rear panel DNC enables the operator to examine the d.c. value, thus, the detectors operating point.

The post-amplifier amplifies the main interferometer signal by the following factors: 1, 3, 10, 30, 100 (corresponding to absolute values of 2 through 200 respectively).

3.3.4 Power Supplies

The power supplies generate ± 12 volts for the operational amplifiers, ± 7 volts for the transducer drive, + 5 volts for the micrologic circuits, + 30 volts for the detector bias, + 1500 volts for the laser, and ± 1000 volts for the piezoelectric crystals. An external ± 15 volt supply (at 1 amp) is necessary to power the level sense circuitry found in the junction box. The three G.R. jacks on the rear of the console accept the external ± 15 volts.

3.3.4.1 Bias Supply

The signal detector bias supply is essentially a 500 kHz square wave oscillator driving a voltage doubler ladder network. The output voltage is connected to a 10 turn potentionemeter with the center tap going to the detector.

3.3.5 Auxiliary Circuits

3.3.5.1 Level Sense

The level sense circuit detects the change in resistance of three resistors in series. The three resistors are strung vertically up from the bottom of the cryogenic tank. With no LN_2 present in the tank, the total resistance is approximately 86Ω. As the level encompasses each resistor, an increase in resistance of 7Ω per resistor occurs. The change in resistance is converted to a voltage change via one operational amplifier. This operational amplifier drives a meter mounted on the junction box. Offset and gain controls are mounted in the junction box for setting the empty and full level readings.

3.3.5.2 Heater Control

The bearing pressure is maintained by pressure switch P2 turning on and off the tank heater. This can be monitored by the Heater On Lamp mounted on the junction box. If the pressure falls below a nominal value, two commands are executed. First, the transducer drive coil is removed from the drive amplifier. Second, line power is removed from pressure switch P2, thus, shutting off the tank heater. During the low pressure status, junction box lamp "Pressure" is turned off and front panel lamp "Low Air Pressure" is turned on. Caution must be employed when going from a low pressure status to normal operating status! (See Section 6.5 for this procedure.)

The pressure overide button overides only the pressure switch command to enable pressure switch P2 (tank heater power). During the time the button is depressed, a false "Pressure" lamp status occurs. The reason for the momentary overide is simply to get the pressure above the nominal value so that the pressure switch P2 can operate.

3.3.5.3 Temperature Monitors

Two low temperature sensors are located on the front and rear of the interferometer cube. These resistances are brought out on rear panel BNC connectors. Figure number Fourteen is a chart for determining the temperature given the resistance readings.

A thermistor located in the signal pre-amplifier is brought through the cables to a network located in the post amplifier card. The network provides a bias for the thermistor and generates a voltage dependent on the temperature. This voltage is available at the "monitor" output and is also fed to the front panel meter which has a scale calibrated in degrees centigrade.

3.3.5.4 Peak Reading Meter & Monitor Switch

The peak reading meter circuit measures the full wave rectified peak values of the siganl selected by the "monitor" front panel control. At the same time this signal appears at the "monitor" output jack.

The monitor switch presents the following signals to the front panel connector, signal, mono, white, velocity error, position error, drive amplifier output and temperature. A timing diagram (Figure Number Fifteen) shows the relative wave shapes that can be observed and their nominal values.

Ω	0	1	2	3	4	5	6	7	8	9
230	51	55	59	63	67	71	76	80	84	88
240	92	96	100	104	108	112	116	120	124	128
250	132	137	141	145	149	153	157	161	165	169
260	173	177	181	185	189	193	197	202	206	210
270	214	218	222	226	230	234	238	242	246	250
280	254	258	262	267	271	275	279	283	287	291
290	295	299	303	307	311	315	319	323	327	331

- Resistance -

- Temperature °K -

FRONT

Ω	0	1	2	3	4	5	6	7	8	9
230	46	51	55	59	63	67	71	75	79	83
240	87	91	95	99	103	108	112	116	120	124
250	128	132	136	140	144	148	152	156	160	165
260	169	173	177	181	185	189	193	197	201	205
270	209	213	217	222	226	230	234	238	242	246
280	250	254	258	262	266	270	274	279	283	287
290	291	295	299	303	307	311	315	319	323	327

- Resistance -

- Temperature °K -

BACK

TEMPERATURE SENSOR CONVERSIONS

FIGURE NUMBER FOURTEEN

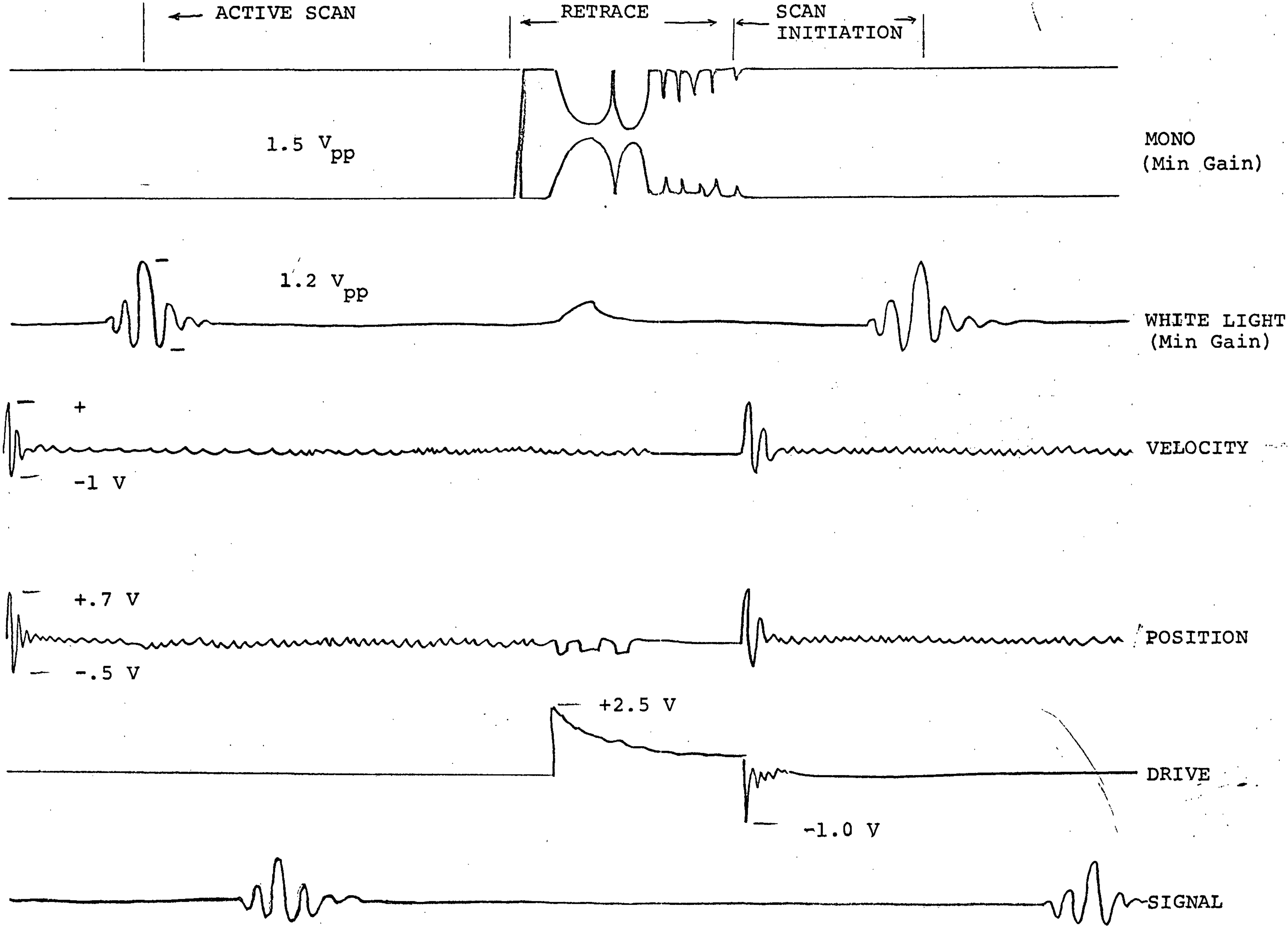


FIGURE NUMBER FIFTEEN

NOMINAL WAVEFORMS AND VALUES

3.3.6 Remote Control

Three front panel controls are wired for remote control operation. These include the Sensitivity, Retardation and Sampling switches. To change sensitivity in the remote mode of operation the front panel switch must be placed in "remote" and +5 volts placed on PINS 1, 2, 3, 4 or 5 of Digital Connector J72. Wiring diagram E-920-22 shows what each pin number represents on the front panel controls. To change retardation in the remote mode of operation, the front panel switch must be placed in "remote" and +5 volts placed on PINS 20, 21, 22 or 23 of Digital connector J72. To change Sampling in the remote mode of operation, the front panel switch must be placed in "remote" and +5 volts placed on pins 6, 7, 8, 9, 10 or 19 at Digital connector J72.

SENSITIVITY	J72 PIN	RETARDATION	J72 PIN	SAMPLING	J72 PIN
100X	5	R1	23	1/2	6
30X	4	R2	22	1	7
10X	3	R3	21	2	8
3X	2	R4	20	4	9
1X	1			8	10
				16	19

SECTION IV

CONTROL FUNCTIONS AND SPECTROMETER OUTPUTS

4.0 General

The following paragraphs contain information concerning the location and function of the various controls and outputs of the interferometer. Before attempting operation of the interferometer, the reader is advised to become thoroughly familiar with this section of the manual as well as the location of the various controls of the spectrometer.

4.1 Front Panel Controls/Outputs

Retardation: A five position switch allows for operation of the interferometer at four different retardations and provides for remotely selectable retardation via the Remote position. Retardations available are listed below.

Switch Position	Retardation
R1	0.25 cm
R2	0.5 cm
R3	1.0 cm
R4	2.0 cm

Sampling: A seven position switch determines the sampling interval in multiples of 0.6328 microns in steps of two from 1/2 to 16 and provides remotely selectable retardation via the Remote position. Sampling intervals available are listed below.

Switch Position	Sampling Interval
1/2	0.31 microns
1	0.63 microns
2	1.26 microns
4	2.53 microns
8	5.06 microns
16	10.12 microns

Monitor Selector/Meter: The monitor system is provided to allow quick examination of a number of internal signals to determine the operational status of the instrument. In addition to directing these signals to the meter located directly above the selector switch, the signal is presented at one of the BNC connectors available on the front panel. The various signals presented are:

Signal: This is the detector output following the post amplifier.

Mono: This is the monochromatic interferogram produced by the laser in the reference interferometer.

White: This is the white light interferogram produced by the reference interferometer.

Velocity: This signal is proportional to the velocity error of the moving mirror (i.e. the deviation from a constant velocity.)

Position: This signal is the integral of the velocity error.

Drive: This signal is the actual voltage as applied to the coil in the electromechanical transducer assembly.

Temp: This signal is the temperature in degrees Centigrade as indicated by a thermistor located in the pre-amplifier enclosure.

Power: The spectrometer is designed to operate on 115V 60Hz through a standard U-ground power cord. The on-off switch is a two position switch which activates all power supplies within the instrument. The system is provided with an indicator light and is fused with a 2 amp fast blow fuse.

Bias/Bias Monitor: A ten turn potentiometer is available for adjusting the DC bias on the detector to allow operation of the detector under varying background conditions. The bias is adjustable from 0 to 28 volts and may be monitored on the BNC connector located directly below the adjusting potentiometer.

Velocity: A ten turn potentiometer is provided to allow an approximate 10% change in the absolute velocity of the moving mirror.

Low Air: If the pressure across the bearing drops to below 15 psi the bearing pressure switch will open disabling the drive. When this occurs, the low air pressure lamp will turn on.

Mirror Position: Three potentiometers are provided for varying the applied voltage to the piezo electric crystals on the fixed mirror assembly. The voltage is varied from -1000 volts to +1000 volts as the pot is rotated clockwise.

Output Signals: Eight BNC connectors are located on the front panel of the controller. They are:

MONITOR: As previously mentioned, this connector allows observation of signals as selected by the monitor switch.

SIGNAL: This connector presents the detector output following the post-amplifier.

WHITE: This connector presents the white light interferogram from the reference interferometer.

SYNC: This signal is shown in Figure Number Seven and would normally be used for applications involving the use of a tape recorder.

TRIG: This signal is low during the inactive portion of the scan and high during the active scan. This would normally be used as a necessary logic level for operation of the spectrometer in conjunction with a Digilab, Inc. data system without the use of intermediate playback devices.

CLOCK: This a digital square wave which corresponds to the sampling interval and also would be employed for operation of a Digilab, Inc. data system without the use of intermediate playback devices.

SCOPE TRIG: This signal is provided for the purpose of providing a trigger for an oscilloscope. This trigger signal precedes the white light interferogram from the reference interferometer.

EXT DRIVE: This connector serves as the input point for waveforms to the drive amplifier when performing alignments and tests.

4.2 Rear Apron Controls/Outputs

Signal: The BNC connector to the left side of the rear apron is the D.C. coupled signal from the pre-amplifier.

Remote: The Amphenol connector located in the center of the apron is the remote control connector.

Temperature, Front and Rear: Two BNC connectors are provided for monitoring temperature sensors located on the interferometer cube (front) and the flange which mates to the main bulkhead (rear).

± 15V DC: Three binding posts are used to deliver ± 15V DC to the liquid level sensing network.

Transducer Position: A potentionmeter is provided for moving the transducer manually when the spectrometer is in the manual position.

Connectors: The connectors provided are used to connect the control chassis with the junction box on the optical head.

4.3 Junction Box Controls/Outputs

Gain White: A ten turn potentiometer is adjustable through the front panel and is used to change the gain of the reference white light pre-amplifier.

Gain Mono: A ten turn potentiometer is adjustable through the front panel and is used to change the gain of the monochromatic pre-amplifier.

D.C. Offset: A ten turn potentiometer is adjustable through the front panel and is used to change the D.C. offset of the monochromatic pre-amplifier output.

Level: A meter is provided to indicate the liquid level within the spectrometer. Three discrete levels are indicated corresponding to one-half, three-quarters and completely full.

Heater On: When the immersion heater is activated, the indicator lamp is turned on.

Pressure: When the pressure within the cryogen tank is sufficient to allow operation of the spectrometer this lamp is turned on.

Low Pressure Override: This switch allows a manual override of the low pressure cut out switch activating only the immersion heater but not the transducer.

Immersion Heater Connector: A Bendix connector located on the side of the support connects the immersion heater to the control system.

Controller Connectors: The side of the junction box contains the connectors for the cables from the controller.

SECTION V

ALIGNMENTS AND ADJUSTMENTS

5.0 General

This section outlines the alignments and adjustments which from time to time may be required to keep the instrument in good running order. The optical adjustments necessitate removal of the optical head and the attention of the reader is directed to Section 6.1, Removal of Optical Head. Electrical adjustments do not necessarily require removal of the optical head from the tank assembly.

Test equipment required for the procedures outlined consist of a signal generator capable of 5-10 Hz operation with amplitude adjustable for 0 to 20 volts and a dual beam oscilloscope.

5.1 Reference Interferometer Alignment

Complete reassembly of the reference interferometer should never be necessary. However, in the interest of completeness, a brief outline of the complete alignment procedure is presented.

Set the reference frame into its receptacle and replace the five screws (finger tight). Using a right angle reference device (e.g. a small square) align the top of the reference frame to the flange immediately behind the cube. Place the drive amplifier in the manual mode and turn the instrument power on. Using the light from the white light, move the reference frame parallel to the flange to obtain best alignment of the apex of the moving corner cube with the fixed corner cube. Tighten the reference frame screws snugly. Square the reference frame alignment jig with the reference frame and tighten solidly. Replace the laser mirror and align this item to give maximum output on the mono (viewed via monitor jack). In a random fashion, tighten the five screws on the reference frame to give a maximum output. Now place the instrument in the sweep position and examine the white light channel for a white light interferogram. If present but not triggering the instrument, increase gain of white light preamp to maximum gain position. The white light is maximized by moving the slide rail assembly up and down in a controlled fashion by placing a screw in the adjustment jig attached to the bottom of the cube. Iterate to the maximum white light position using the reference frame and the slide height adjustment. If the nominal value for white light is not obtained move the reference frame parallel to the mounting flange in small increments ($\pm$.001 inch) using the reference frame alignment jig as a guide. The nominal value for the white light amplitude is given in Figure Number Fourteen.

5.2 Signal Interferometer Alignment

To perform the alignment it is first necessary to provide a source and detector for the interferometer to produce an electrical signal on which the alignment may be peaked. Assuming this has been accomplished, insert the pinion gears into the fixed minor assembly and with the interferometer scanning, adjust for maximum interferogram size.

It is recommended that the piezo-electric controls be set at the 12 o'clock position prior to mechanical alignment so that full adjustment capability is available during cooldown.

5.3 White Light Sheer

White light sheer is defined as the equivalent physical separation of the signal white light position and the reference white light position. (Refer to Figure Number Seven, Typical Waveforms) To adjust the sheer, the reference frame is simply moved forward and back as required, using the reference frame adjustment plate to maintain previous alignment and control the amount of movement.

5.4 Monochromatic Preamplifier Offset

The DC coupling of the laser signal allows other sections of the electronics console to detect when the laser is completely off or its output is below a preset threshold. These conditions may be caused by a failure of the laser in the case of no output or misalignment of the laser or deterioration of the laser output, in the case of low output. The monochromatic preamplifier offset can be observed through the monitor jack with the selector switch on MONO. When the DC level of this signal goes below approximately minus five volts, the logic circuitry commands the servo to stay in the reset condition. This is easily observed. With the instrument running, obstruction of the laser beam should stop the instrument from scanning and the transducer should move back against the stops and remain there until the obstruction is removed. The adjustment potentiometer is adjusted through the front panel of the junction box. The adjustment is made as follows: Obstruct the laser beam and adjust the offset potentiometer for a DC offset of approximately minus five volts.

A slight modification of the above procedure is necessary when the optical head is within the cryogen tanks since the laser cannot be obscured physically. To simulate the obscured beam turn the instrument power off, disconnect the high voltage cable, turn the instrument power on and adjust the DC offset level. Then turn the instrument off, reconnect the laser cables and turn the power on.

5.5 Monochromatic Preamplifier Gain

The monochromatic gain potentiometer is available through the front panel of the junction box. The adjustment is made to bring the laser to a level of approximately two volts peak-to-peak.

NOTE: The monochromatic preamplifier offset and gain controls are interactive. Therefore, when one adjustment is made, the other signal should be noted as being proper before continuing operation.

5.6 White Light Preamplifier Gain

The reference white light gain can be changed by adjusting the potentiometer available through the junction box front panel. The gain should be adjusted such that the sync is generated on the peak of the white light interferogram. The white light threshold is approximately 0.6 volts positive.

5.7 Velocity Adjustment

The velocity of the moving mirror can be adjusted by approximately 10% via a trimpot available through the front panel of the controller. The velocity can be determined by observing the frequency of the monochromatic output.

SECTION VI

OPERATING AND MAINTENANCE PROCEDURES

6.0 Preliminary Precautions

The following sections deal with the normal operating and maintenance procedures. Again, the reader is cautioned to familiarize himself with the contents of this section in its entirety before attempting operation of the instrument.

Before running the instrument two cautions are advised:

1. NEVER ACTUATE THE "SWEEP/MANUAL" SWITCH WITH INSTRUMENT POWER ON. THE TRANSIENT MAY DAMAGE THE INSTRUMENT.

2. THE HEATER CARTRIDGE SHOULD NEVER BE CONNECTED EXCEPT DURING THE AUTOMATIC OPERATION PORTION OF THE RUN CYCLE.

6.1 General Comments

In order to assure proper cooldown of the cryogenic interferometer, certain instructions and safety precautions must be followed.

The following instructions should be performed in the steps indicated to insure proper operation. A purge cycle is initiated prior to actual cooldown of the instrument. This cycle performs the task of room temperature check-out of the instrument and assuring that no moisture or other contaminants are within the cryo-chamber or associated plumbing. The fill procedure defines that period of actual liquid nitrogen transfer into the cryochamber. During this time various electronic signals are monitored as well as the instrument inside temperatures. These temperatures indicate the rate of cooldown and any temperature gradients which might exist during this phase of operation. The pressure build-up procedure defines that period in which the instrument has been filled with cryogen and is being prepared for full automatic operation. The top-off procedure is carried out after the liquid nitrogen level has dropped below the usable range as indicated by the liquid level sensor. A dump procedure is followed when the instrument has completed its function and is ready to be brought up to room temperature. This is followed by a warm-up cycle. Instrument warm-up is as important a function as the proper purge and filling cycle for proper operation of the cryogenic interferometer.

The detector procedures for filling and top-off will be covered in the section on detector preparation and operation.

6.2 Controls and Their Functions

A. Fill Valve. A 1/2" valve admits cryogen into the cryo-chamber and can be use to control the flow of cryogen such that the rate of liquid nitrogen transfer can be controlled.

B. Dump Valve. This valve serves two functions: (1) to allow thorough purging of the cryo-chamber; (2) provide a method for dumping of cryogen for the start of a warm-up cycle.

C. Outer Tank Manual Relief Valve. This valve is actuated during various procedures and serves a main controlling function. The manual relief is opened for purging the gaseous nitrogen bearing lines, used to control cryogen pressure and flow rate into the cryo-chamber, and closed for the pressure build-up cycle.

D. Outer Tank Automatic Safety Relief. The safety relief valve is set to relieve excessive gaseous nitrogen pressure build-up in the cryo-chamber. It is this relief coupled with the heater pressure sensor which make up the automatic pressure regulating system.

E. Inner Tank Automatic Safety Relief. This relief has been preset to discharge excessive pressure build-up in the inner instrument chamber.

F. Rupture Disk Safety Bonnets. Two rupture disks have been incorporated to provide safety from over pressurization of the instrument. One bonnet is located on the outer tank and one on the inner tank. Each disk has been calibrated at liquid nitrogen temperatures for a rupture pressure of 75 psi.

G. <u>Instrument Pressure Gauge</u>. A large, easy to read pressure gauge calibrated from 0-30 psi indicates both liquid and gaseous nitrogen pressure heads, i.e. the pressure in the outer tank.

H. <u>Heater Pressure Sensor</u>. This device monitors the pressure of the outer tank and actuates a switch when the pressure in the tank is below the minimum operating pressure. The switch is in turn connected to a cartridge type immersion heater which when actuated stimulates nitrogen boil off until the proper operating pressure is attained. Heater operation is monitored by a panel light on the electronic junction box. When power is applied to the heater, the lamp is turned on. The sensor itself is located on the left hand pedestal of the forward bracket.

I. <u>Low Pressure Cut-Out</u>. To provide maximum safety and reliability in operation a second pressure sensing control is incorporated into the system. Its purpose is to continually monitor the bearing line pressure just prior to the bearing. If this pressure drops below a minimum value two precautions are taken: (1) the drive coil is disconnected; (2) the heater circuit is disrupted so that the element will not function. This pressure is set below that of the heater cycle. The sensor is located on the right hand pedestal of the forward support bracket.

J. <u>External Nitrogen Bearing Feed</u>. A valve has been provided on the low pressure cut-out control so that external gaseous nitrogen may be applied during cooldown. This has been done because the normal external liquid nitrogen supply may not be capable of maintaining sufficient pressure to insure running of the instrument while cooling. Additionally, if sufficient LN_2 feed pressure is available line surges may preclude smooth operation during a cooldown. A check valve located inside the instrument prevents this external nitrogen from interfering with the incoming LN_2 supply. This nitrogen feed is also used in the purge cycle.

K. <u>Window Jets</u>. Four valve stems are located around the interstage flange and control the flow of cold nitrogen gas from the inner chamber to the outside of the entrance lens. Its purpose is to keep the lens from frosting. These valves are closed for operation into an evacuated chamber, and open for room temperature operation.

6.3 Purge Procedure

A. Connect liquid nitrogen supply to fill valve.

B. Connect gaseous nitrogen supply to external nitrogen bearing feed.

C. Open the following valves:

1. Dump valve
2. Manual relief valve (both inner and outer tanks)
3. Fill valve
4. External nitrogen bearing feed

D. Apply 20 psig pressure to the external nitrogen bearing feed. This applies sufficient bearing pressure to operate the instrument.

E. Begin to apply liquid nitrogen gas pressure to the cryo-chamber. This should be done slowly and with caution not to allow liquid nitrogen to enter the cryo-chamber.

F. Allow this operation to continue for 15 minutes. This will thoroughly purge the cryo-chamber and lines.

G. Close the dump valve and the external nitrogen bearing feed valve. This will divert more of the purging nitrogen gas to reach the inner tank plumbing and gas collector block. Monitor the tank pressure gauge so that a pressure of not greater than 5 psig is applied during this procedure.

H. Continue this procedure for 15 minutes at which time the filling procedure may be followed.

6.4 Fill Procedure

Reapply pressure via the external nitrogen feed valve and establish an operational condition of the instrument. With the instrument in operation and all signals normal, increase the liquid nitrogen flow so that the liquid phase is transferred. Monitor both the front and rear temperature sensors using a suitable resistance bridge. Care should be taken not to allow a temperature differential of greater than 10°K to exist between the front and rear monitoring points. If such a differential does exist then stop transferring LN_2 and allow for equilibrium of these temperatures. The cryo-chamber tank pressure can be allowed to exceed 10 psig if desired.

While filling, monitor all signal outputs from the reference amplifier. As cooling continues adjustments will need to be made in the white light and monochromatic preamplifier gains and the D.C. offset. These should be accomplished at the appropriate times as determined by the levels of the signals. (Refer to Sections 5.4, 5.5, and 5.6.)

6.5 Pressure Build-Up Procedure

When the liquid level sensor indicates the last resistor has been immersed, liquid transfer should continue until the liquid phase begins to come out the outer tank manual relief valve. At this point the instrument cryo-chamber is full. Close off the manual relief valve and fill valve. Close off the liquid nitrogen tank supply. Caution should be exercised not to trap liquid nitrogen between the fill valve and tank supply. Disconnect the supply line from the tank if not fitted with the proper safety relief devices.

Remove the instrument line cord, connect the heater cartridge, and replace the instrument line cord. At this point pressure in the main tank should begin to build-up. If the pressure does not build-up to an operating condition by itself, depress the pressure override switch until the system latches as indicated by the heater lamp going off. Allow the pressure to build-up to 20 psig before starting the automatic operation procedure.

6.6 Automatic Operation Procedure

Place the instrument into manual operation. With 20 psig indicated on the tank pressure gauge, close the external bearing feed valve. This allows the check valve to open and allow the boil off nitrogen to flow to the bearing. Allow 15 minutes for stability of the bearing to take place. Place the instrument in automatic sweep operation. This completes the procedure.

When going to any other condition other than a top-off procedure, the heater cartridge must be deactivated.

6.7 Top-Off Procedure

Once the level indicator has dropped below the level indicated for proper operation a top-off procedure should be initiated as follows:

1. Place the instrument into manual mode.
2. Open fill valve.
3. Open manual relief valve.
4. Start liquid nitrogen flowing into system.
5. Continue until the liquid phase appears at the manual relief valve.
6. This procedure assumes that the instrument remains in manual mode during the top-off procedure.
7. Follow the procedures for pressure build-up and automatic operation.

6.8 Dump Procedure

This procedure is given in the event the instrument has completed its function and is required to be left unattended for a long period of time. Given are the following instructions to complete the dump phase.

1. Place the instrument in manual operation.
2. Close the fill valve if not already closed.
3. Connect a suitable line to the dump valve and direct to a storage vessel for LN_2.
4. Open the dump valve and discharge the liquid nitrogen.

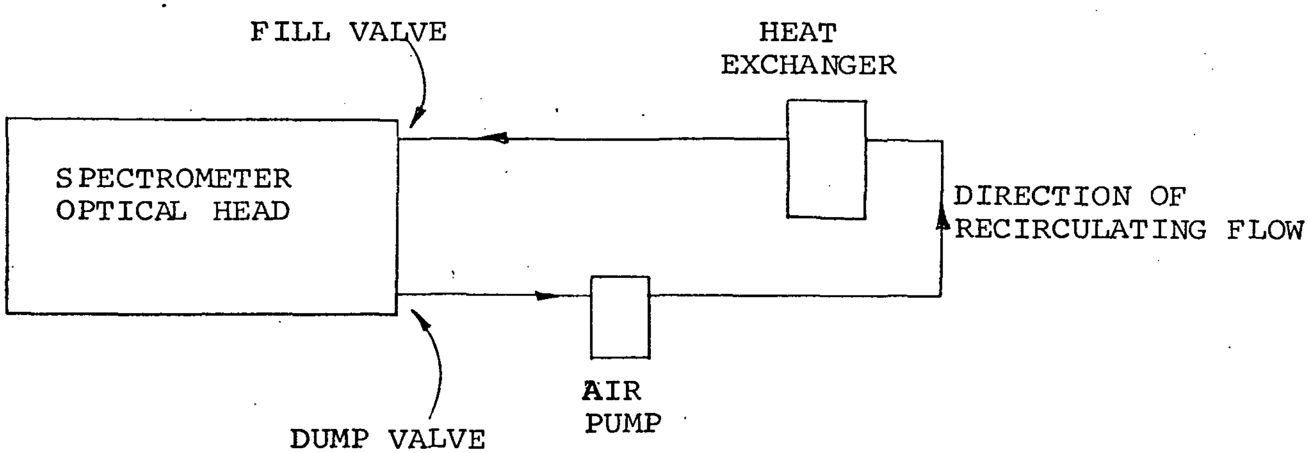
<u>NOTE:</u> Assure that the window jets are closed tight.

5. When the liquid ceases to flow there will be approximately 1/2" of LN_2 left in the cryo-chamber.
6. Close the dump valve. Tank pressure may begin to rise but will not be harmful to the instrument since the safety reliefs provided will discharge this pressure.

6.9 Warm-Up Procedure

In the event the instrument detector must be removed for changes in the cold filters, a fast warm-up may be desired. A simple procedure outlined below will hasten the warm-up period to 12 hours rather than the normal 24 to 36 hours warm-up.

1. Follow the normal "Dump Procedures".
2. Connect a high volume pump, heat exchanger and plumbing per diagram.



3. With the fill valve, dump valve and manual relief valve closed, turn on pump. Immediately open the dump and fill valves. This procedure minimizes the amount of warm air admitted into the cryo-chamber and the recirculation of nitrogen gas from the tank in closed cycle fashion is very efficient.

4. In the event that pressure in the tank builds-up, the manual relief valve may be actuated to relieve this pressure. Extreme caution should be exercised not to allow outside air from being admitted into the tank. A simple balloon tied to the relief valve and purged with dry nitrogen will prevent outside air contamination.
5. As a further aid to warming, the external nitrogen bearing feed may be started once more.
6. Monitor the inside temperatures before attempting to admit outside air to any part of the interferometer. The inside temperature must be above the dew point temperature for absolute safety.

6.10 Maintenance Procedures

The three sections which follow present the three items which will require either appropriate cautions or an explanation as to procedure. These are: a description of the procedure to be followed in the event the optical head is to be removed from the main tank, replacement of the bearing feed line filter, and general maintenance requirements.

6.10.1 Removal of Optical Head

As a general word of caution, at no time should the spectrometer optical head be opened (this includes removal of the detector) when there is danger that the inside temperature is below the dew point. The following is a list of items which must be removed from the instrument optical head to allow removal of the interferometer.

1. The detector is removed by first disconnecting the preamplifier to junction box cable and then removing six #6 cap screws from the bottom flange of the detector dewar.

2. Remove the stainless steel tube from the collector block to the left hand pressure switch.

3. Remove the stainless steel tube from the bulkhead to the right hand pressure switch.

4. Disconnect the heater cartridge connector and remove the heater cartridge.

5. Remove the interstage flange assembly.

6. Remove the pressure gauge, street elbow, tee and 1/8 to 1/4 inch tubing fitting as an assembly.

7. To the side of the collector block remove the safety relief; remove valve and nipple; remove elbow, tee and nipple as an assembly.

8. Remove the handle on the inner tank relief valve; remove valve and nipple; remove rupture disk and tee into bulkhead as an assembly.

9. Remove the fill valve and nipple; remove the rupture disk and tee into bulkhead as an assembly.

10. Remove inner tank safety relief.

11. Loosen the swagelock fitting then remove the four screws on top of collector block; and remove and unscrew inner stem assembly; unscrew collector block. (Note: Inner stem assembly does not and should not use teflon tape pipe dope).

12. Remove handle on dump valve; remove valve and nipple; remove elbow from bulkhead.

13. Set the entire instrument tail down on the floor (entrance of spectrometer looking up).

14. Remove backing nuts on dump and fill outlets.

15. Remove five Allen cap screws on outer bolt circle; remove four Allen cap screws on inner bolt circle. (Note: The inner four bolts are backed with indium seals and should be reassembled in the same manner.)

16. Remove the four screws which hold the junction box into the support bracket, remove the seven spade lugs from the terminal strip and swing the junction box clear of its normal position.

17. Separate the faceplate from the main tank by approximately two inches and rest the plate on suitable blocks between the tank and the faceplate.

18. Remove the tubing connection immediately behind the single stainless steel bulkhead fitting. At this point the faceplate is ready to be removed.

19. Prepare a suitable resting place to the right side of the instrument and approximately the same height, then carefully remove the faceplate and place on this surface.

20. Disconnect the level sense lead connection (yellow and orange twisted pair.)

21. Loosen the hose clamps which hold the check valve on the upper left hand stay rod and slide the item off the end of same.

22. Break the bearing feed connection on the upper right hand corner of the cube.

23. Carefully remove the four stay rods.

24. Using spacers provided (two per rod) in the handle kit, reinsert two of the stay rods into the threaded holes located counterclockwise from the upper left hand and lower right hand stay rod positions.

25. Install the handle provided between the two reinserted stay rods.

26. Verify that the platform provided is prepared to receive the optical head.

27. Carefully withdraw the optical head from the tank and mount securely in the test platform.

28. Connect an appropriate air supply (filtered and regulated to ~18 psi) to the bearing inlet.

29. Connect the two blue leads on the junction box to simulate closed pressure switch and carefully shield the others. (Note: These extra wires have line voltage on them.)

30. Reconnect the chassis and junction box cables.

At this point the instrument is ready to be operated.

For reassembly, repeat the above steps in reverse order with the following additions:

a) Prior to reassembly, all fittings should be thoroughly cleaned of old teflon tape and retaped with exceptions as noted above. (Step 11)

b) When reinstalling stay rods (Step 23) leave stay rods fairly loose. The four Allen cap screws (Step 15) are started in the stay rods through the faceplate and only then are the stay rods tightened with access through the entrance port of the interferometer.

6.10.2 Replacement of Nitrogen Line Filter

An item requiring maintenance is a replaceable element in the line filter located in the gas collection block below the pressure gauge. It is quite simple to remove and replace the filter element following these instructions:

1. Remove the stainless steel line to the heater control unit (left side of instrument).
2. Remove four 8-32 Allen cap screws.
3. Loosen the swagelock fitting around the neck of the shaft going into the collector box.
4. Remove the center rod by unscrewing the gauge and shaft assembly. This removes the whole filter mechanism.

5. Remove the gauge and fittings to extract the filter cartridge.

6. Clean all the stainless steel tubing and top cap.

7. Clean and replace the "O" ring on the collector block if necessary.

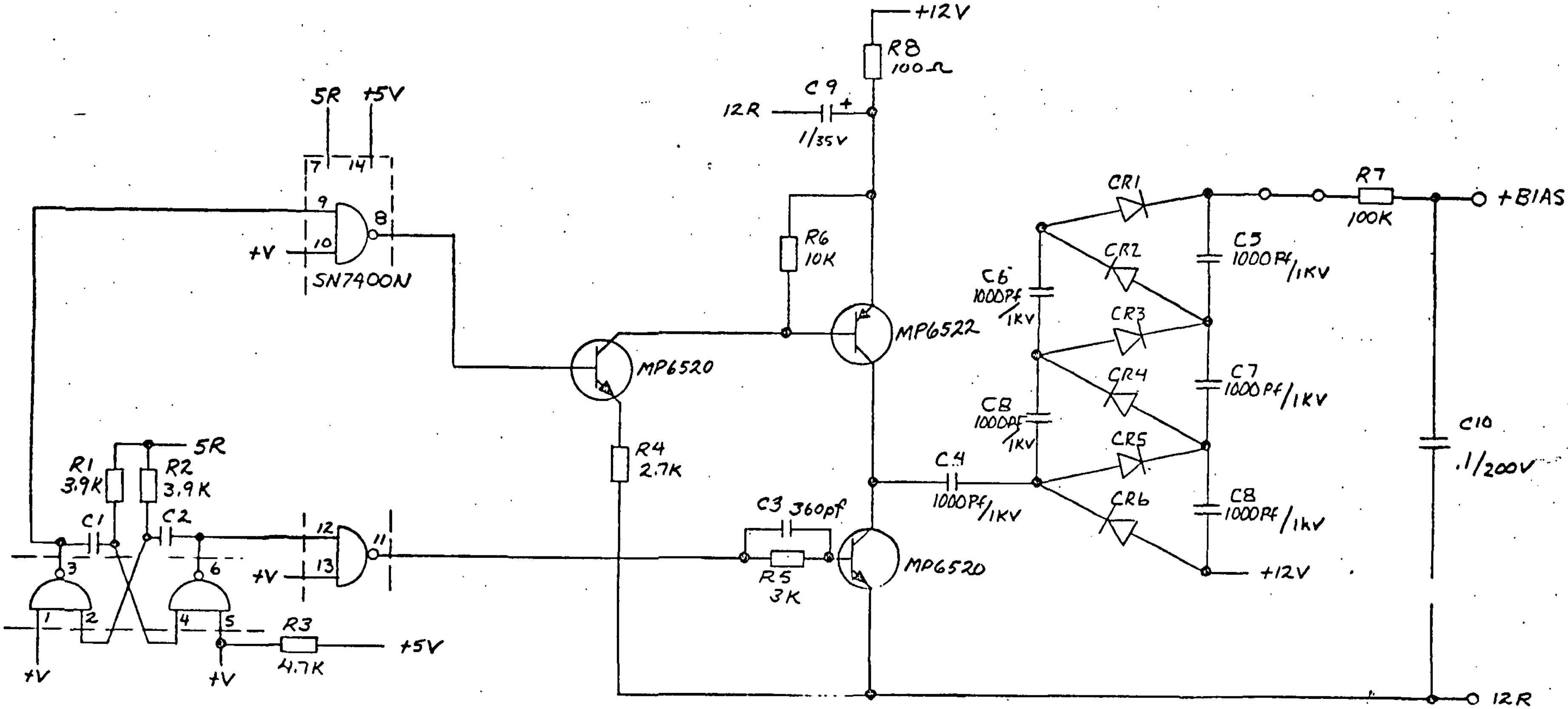
8. Reassemble the filter in the reverse order, observe that the stainless steel square cap compresses the filter cartridge to insure a tight fit. A light film of vacuum grease on the "O" ring will insure a good seal.

6.10.3 General Maintenance

No other special instructions are necessary for any part of the instrument, however, several general comments should be mentioned with regards to maintenance. An "O" ring seal under the detector must be inspected and cleaned after every detector removal. If cracked or chipped it should be replaced. The front entrance lens should be inspected for moisture and cleaned with alcohol if necessary. Since moisture does collect during cold operation, a thorough drying of the exterior should be accomplished after each run.

SECTION VII

ELECTRONIC SCHEMATICS



NOTES:

1) C1 = 390pf, C2 = 390pf

2) CR1-6 = 1N4148'S

QTY REQD	DESCRIPTION	PART OR IDENT NO.	ITEM NO.
	LIST OF MATERIALS		

	CRYOGENIC
NEXT ASSY	USED ON
APPLICATION	

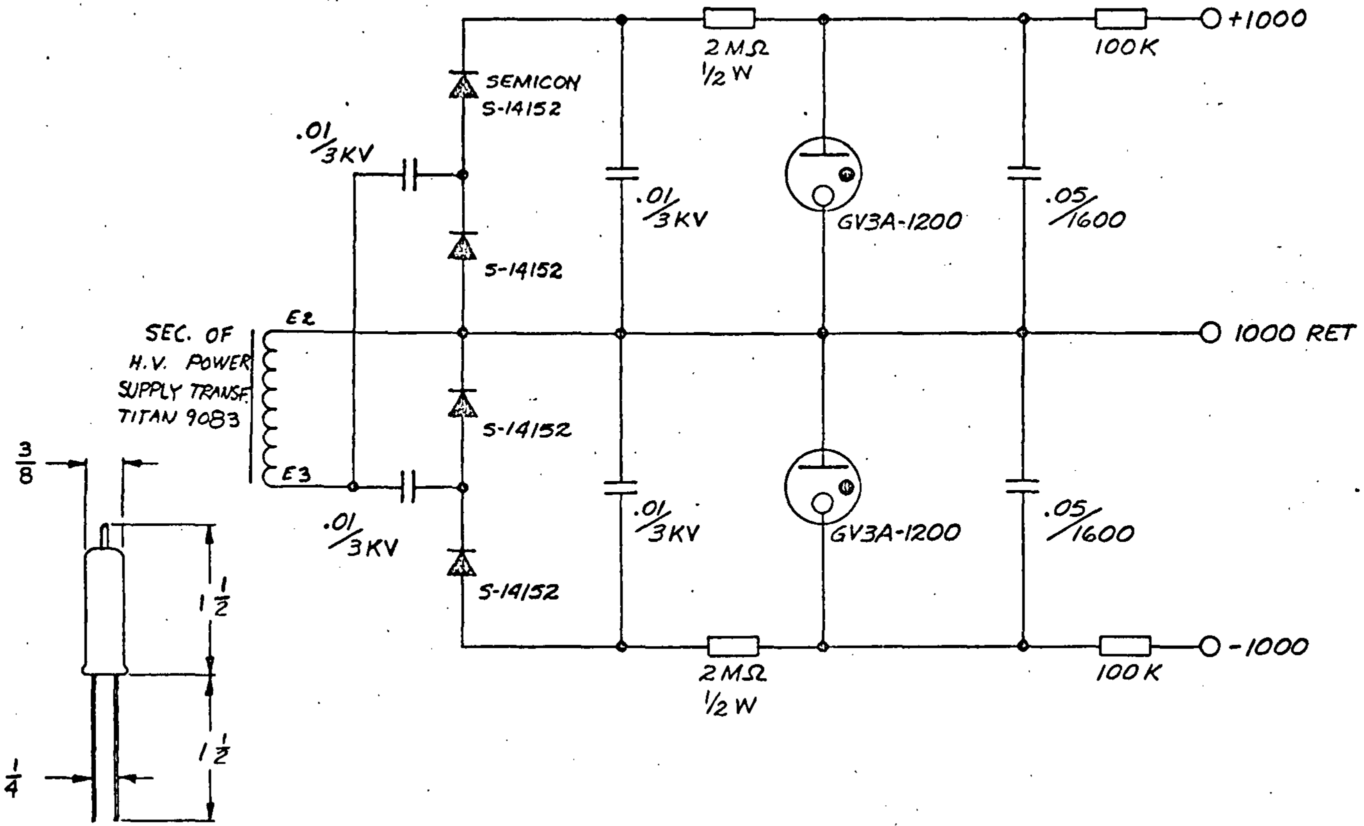
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONS ± 1/64 — DECIMALS .X ± .020, .XX ± .010, .XXX ± .005
ANGLES ± 0° - 15'
FINISH — MAXIMUM
REMOVE ALL BURRS & SHARP EDGES
DO NOT SCALE THIS DRAWING
MATERIAL
FINISH

DRAWN	E. BUTLER	DATE 27 Sep 71
CHECKED		
APPROVED	AH	27 Sep 71
APPROVED		
ISSUED		

Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS

BIAS SUPPLY

SIZE	CODE IDENT NO.	DRAWING NO.
C		110-48
SCALE		SHEET



NOTES:

1. LASER NOT GROUNDED ON EITHER SIDE

QTY REQD	DESCRIPTION	PART OR IDENT NO.	ITEM NO.

LIST OF MATERIALS

	CRYOGENIC
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONS ± 1/64 — DECIMALS .X ± .020, .XX ± .010, .XXX ± .005
ANGLES ± 0° - 15'
FINISH — MAXIMUM
REMOVE ALL BURRS & SHARP EDGES
DO NOT SCALE THIS DRAWING
MATERIAL
FINISH

DRAWN B.R. Bent — DATE 23SEP71
CHECKED
APPROVED HH — 27 Sept 71
APPROVED
ISSUED

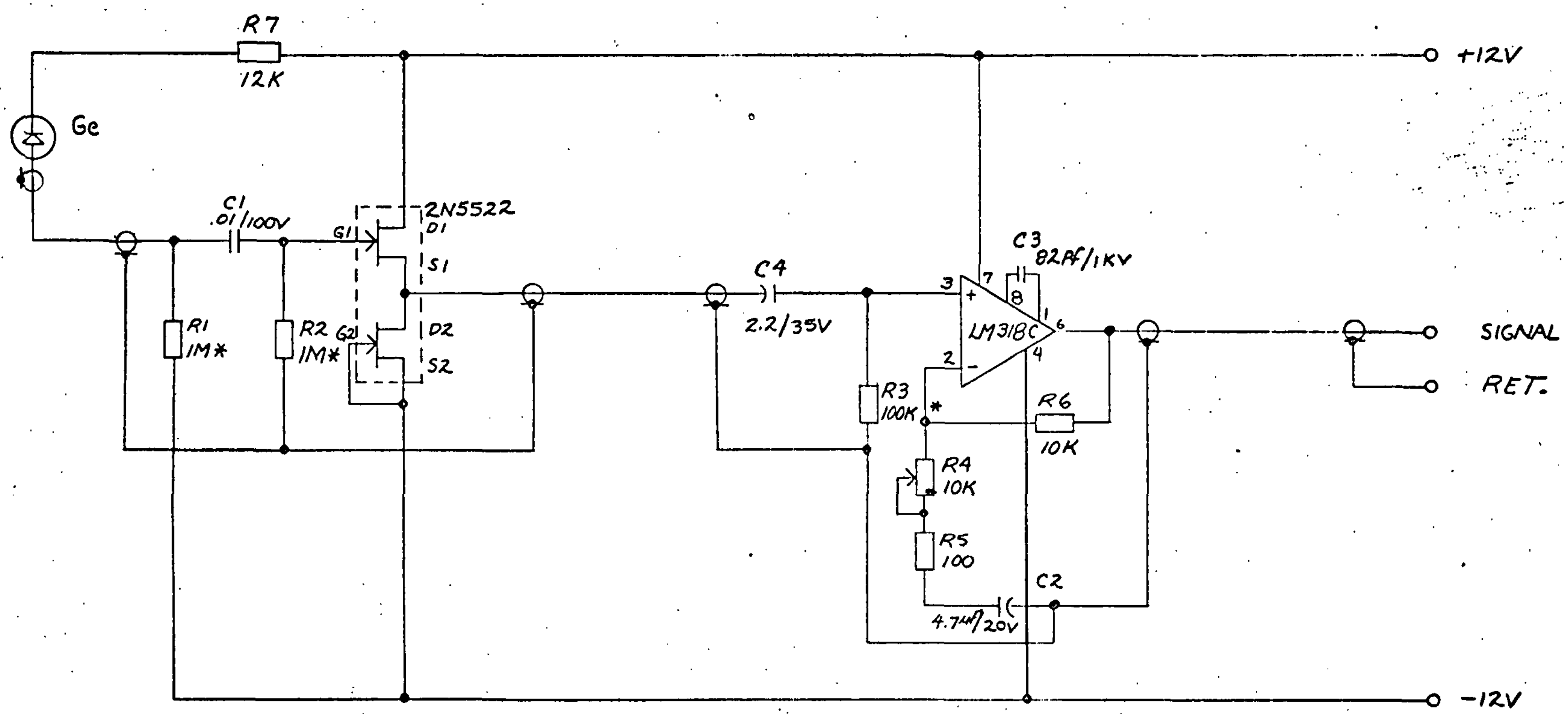
Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS

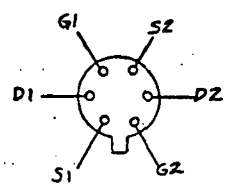
PART OF H. V. SUPPLY

SIZE	CODE IDENT NO	DRAWING NO
C	21351	280-48

SCALE — SHEET 1 OF 1

4 3 2 1





2N5522

QTY REQD	DESCRIPTION	PART OR IDENT NO.	ITEM NO.

LIST OF MATERIALS

	CRYOGENIC
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONS ± 1/64 | DECIMALS .X ± .020 .XX ± .010 .XXX ± .005
ANGLES ± 0° - 15'
FINISH MAXIMUM
REMOVE ALL BURRS & SHARP EDGES
DO NOT SCALE THIS DRAWING
MATERIAL
FINISH

DRAWN	E. BUTLER	DATE 17 Apr. 71
CHECKED		
APPROVED	HH	27 Apr 71
APPROVED		
ISSUED		

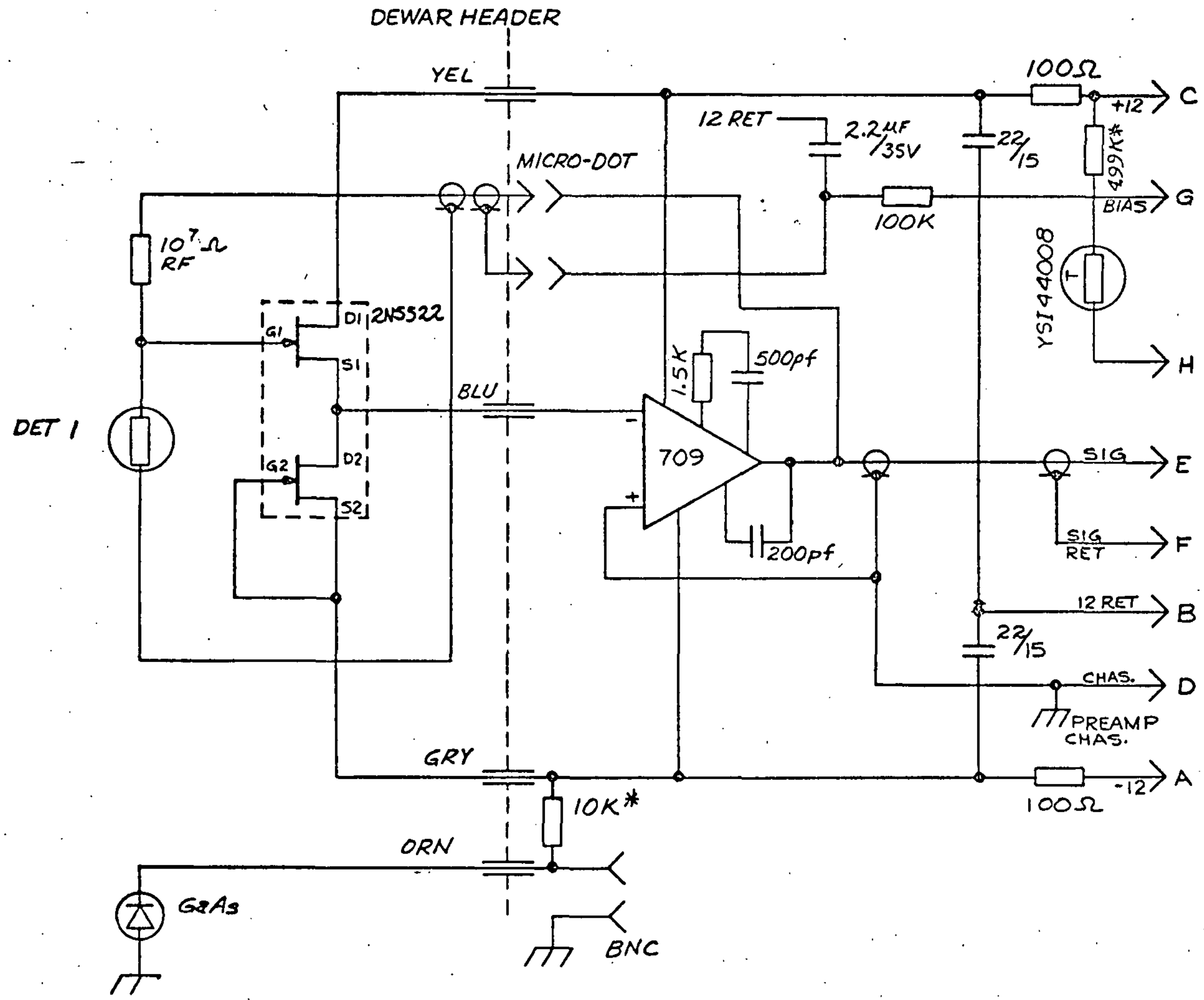
Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS

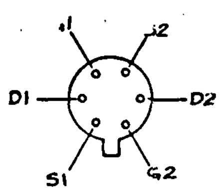
WHITE LIGHT PREAMP

SIZE	CODE IDENT NO.	DRAWING NO.
C		110 - 45

SCALE | SHEET

4 3 2 1





QTY REQD	DESCRIPTION	PART OR IDENT NO.	ITEM NO.

LIST OF MATERIALS

	CRYOGENIC
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONS ± 1/64 — DECIMALS .X ± .020, .XX ± .010, .XXX ± .005
ANGLES ± 0° - 15'
FINISH — MAXIMUM
REMOVE ALL BURRS & SHARP EDGES
DO NOT SCALE THIS DRAWING
MATERIAL
FIN SH

DRAWN	B. R. Bent	DATE 23Sep71
CHECKED		
APPROVED	[illegible]	27Sep71
APPROVED		
ISSUED		

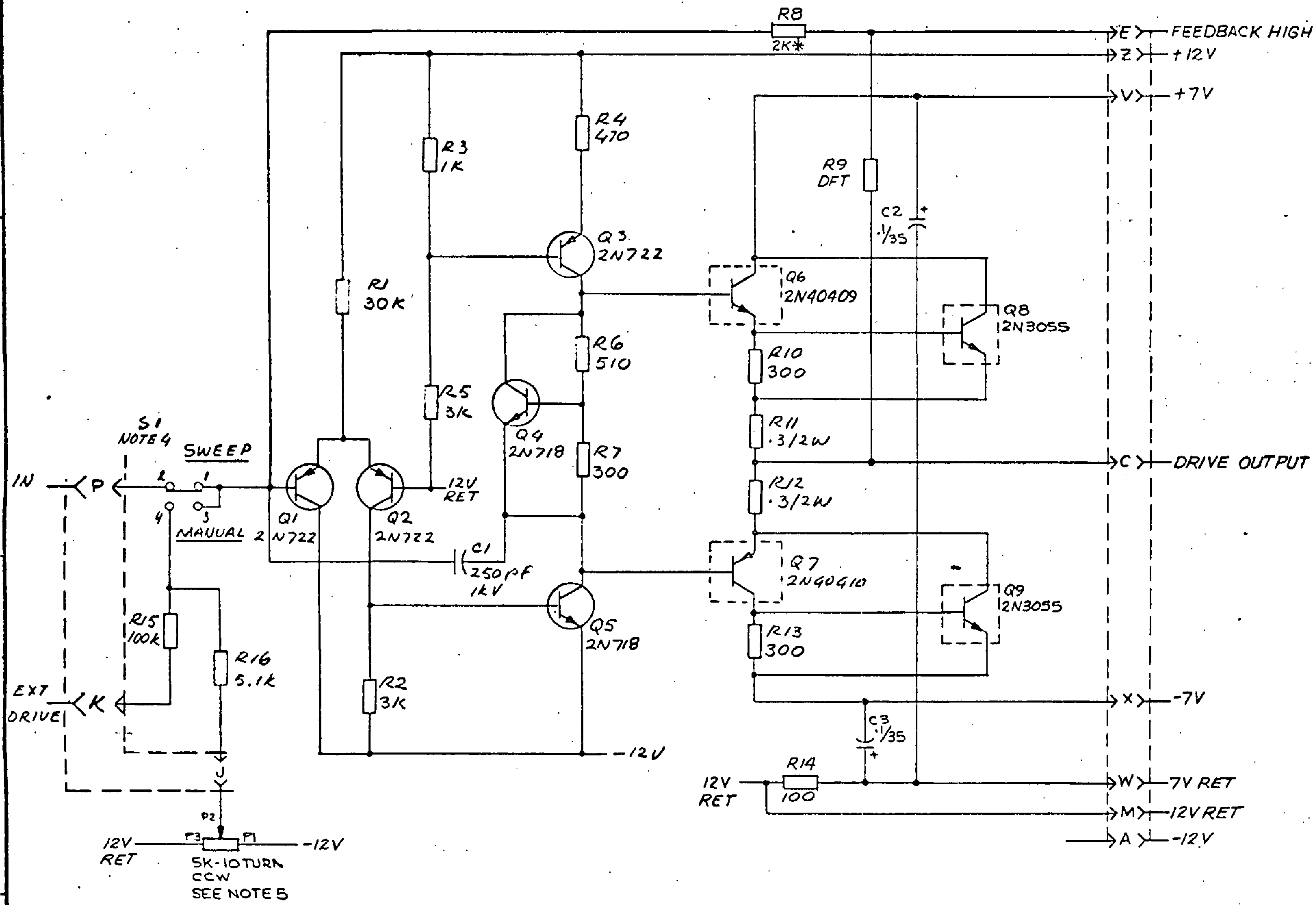
Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS

SIGNAL PREAMP

SIZE	CODE IDENT NO.	DRAWING NO.
C	21351	110-47

SCALE [illegible] — SHEET 1 OF 1

4 3 2 1



NOTES:

UNLESS OTHERWISE SPEC.

1. RESISTORS ARE IN OHMS ±5%, 1/4W. CAPACITORS ARE IN μf / RATED VOLTAGE
2. * METAL FILM 1/8W, ±1%
3. LAST REF.: R16, C3, Q9, S1
4. CONTROL SWITCH: T 2104
5. BOURNS TYPE #3707S-1-502
6. DFT - DETERMINE FINAL TEST

QTY REQD	DESCRIPTION	PART OR IDENT NO.	ITEM NO

LIST OF MATERIALS

CRYOGENIC MODEL 296	
NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONS ± 1/64 — DECIMALS .X ± .020, .XX ± .010, .XXX ± .005
ANGLES ± 0° - 15'
FINISH — MAXIMUM
REMOVE ALL BURRS & SHARP EDGES
DO NOT SCALE THIS DRAWING
MATERIAL
FINISH

DRAWN B. Bent — DATE 10-6-68
CHECKED [illegible] — 11-68
APPROVED R.C. — 11-8-[illegible]
APPROVED
ISSUED

Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS

DRIVE AMPLIFIER

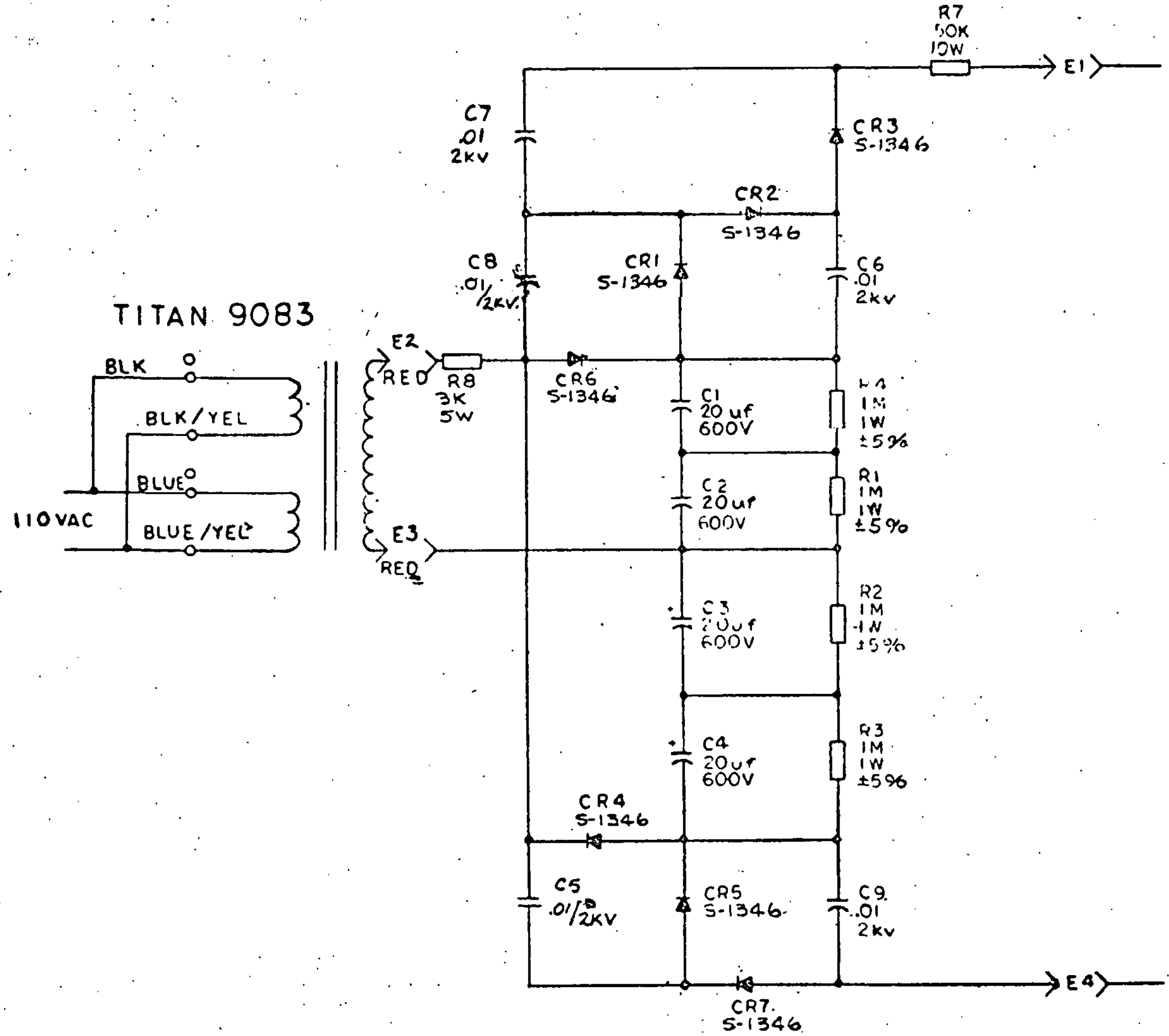
J13

SIZE	CODE IDENT NO	DRAWING NO.	
C	21351	160-29	1

SCALE — SHEET

4 3 2 1

	B	REVISED PER ECO 122	9/11/74	



DELLAB INC

QTY REQD	DESCRIPTION	PART OR IDENT NO.

LIST OF MATERIALS

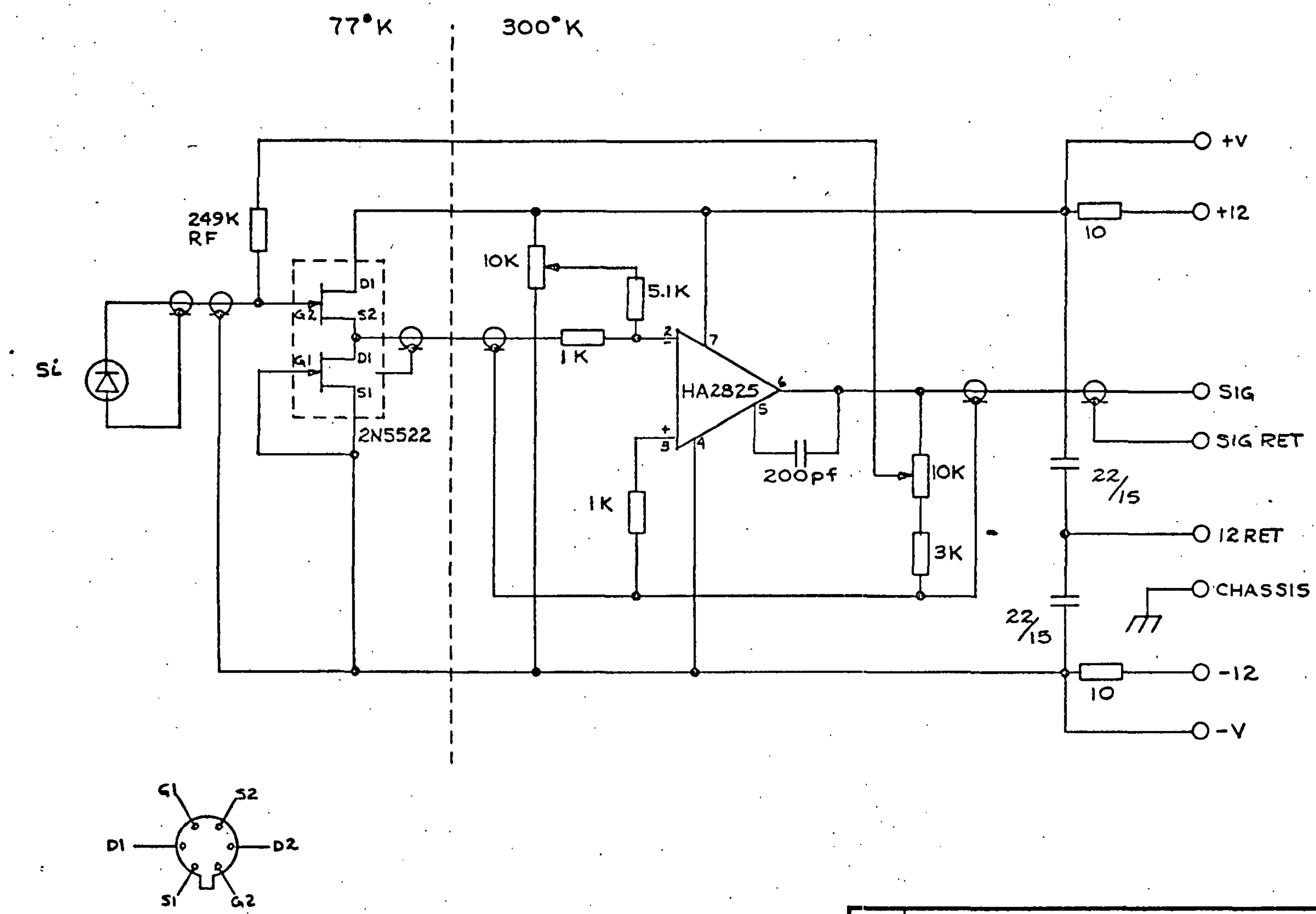
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONS ± 1/64 — DECIMALS .X ± .020, .XX ± .010, .XXX ± .005
ANGLES ± 0° - 15'
FINISH — MAXIMUM
REMOVE ALL BURRS & SHARP EDGES
DO NOT SCALE THIS DRAWING
MATERIAL
FINISH

DRAWN — DATE
CHECKED
APPROVED
APPROVED
ISSUED

	CRYOGENIC
	PT. MUGU
	296
NEXT ASSY	USED ON
APPLICATION	

HIGH VOLTAGE SUPPLY
(ELECTRICAL SCHEMATIC) TB101

SIZE: C | CODE IDENT NO | DRAWING NO: EL-30002
SCALE: NONE | EL 30002 | SHEET 1 OF 1



QTY REQD	DESCRIPTION	PART OR IDENT NO.	ITEM NO.

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONS ± 1/64
ANGLES ± 0°-15'
DECIMALS .X ± .020, .XX ± .010, .XXX ± .005
FINISH — MAXIMUM
REMOVE ALL BURRS & SHARP EDGES
DO NOT SCALE THIS DRAWING
MATERIAL
FINISH

DRAWN B.R. Bent — DATE 23Sep71
CHECKED
APPROVED — 7 Sep 71
APPROVED
ISSUED

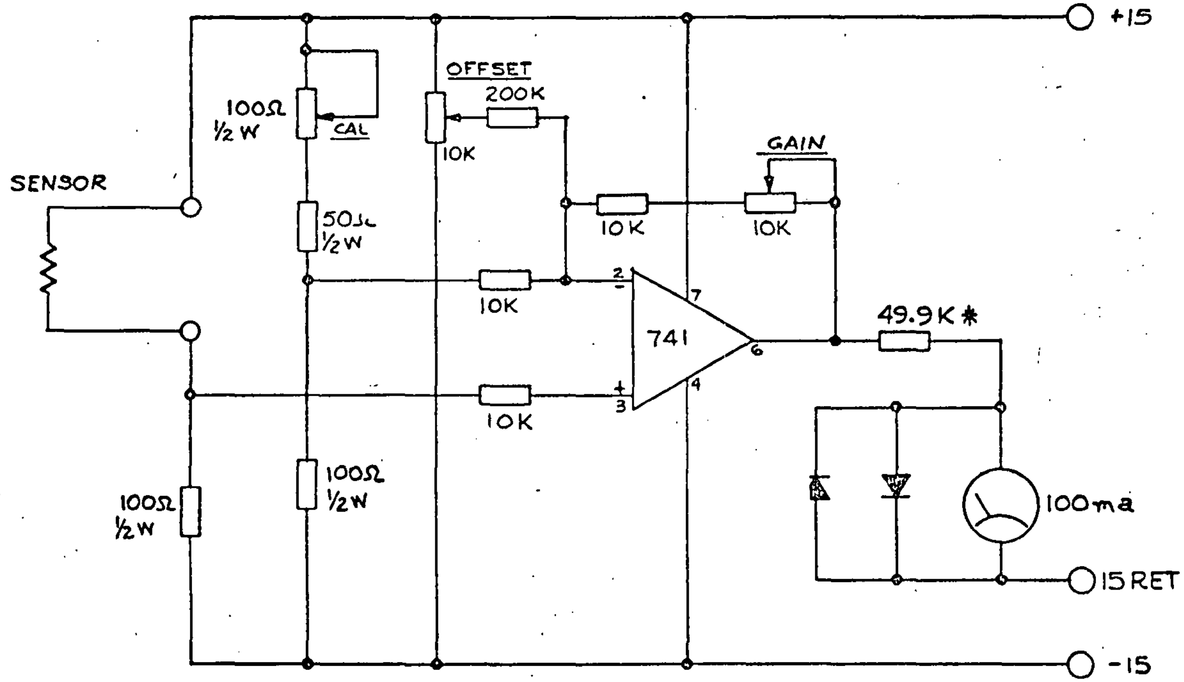
NEXT ASSY	USED ON
	CRYOGENIC

APPLICATION

Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS

Si DET. PREAMP

SIZE C — CODE IDENT NO 21351 — DRAWING NO 110-46
SCALE — SHEET 1 OF 1



QTY REQD	DESCRIPTION	PART OR IDENT NO.	ITEM NO.

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONS ± 1/64
DECIMALS .X ± .020 .XX ± .010 .XXX ± .005
ANGLES ± 0° - 15'
FINISH MAXIMUM
REMOVE ALL BURRS & SHARP EDGES
DO NOT SCALE THIS DRAWING
MATERIAL
FINISH

	CRYOGENIC
NEXT ASSY	USED ON
APPLICATION	

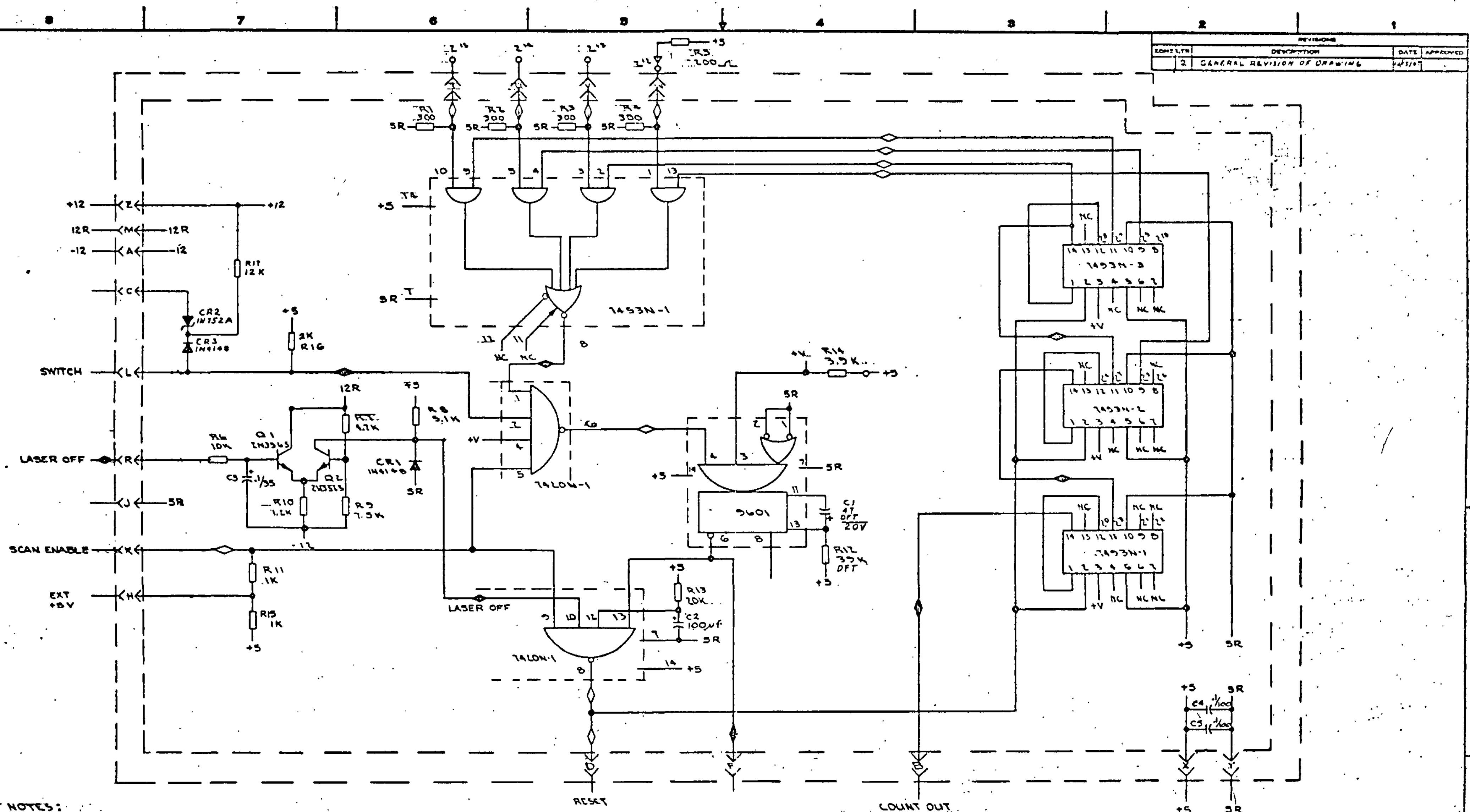
DRAWN B. R. Bent	DATE 23 Sep 71
CHECKED	
APPROVED	
APPROVED	27 Sep 71
ISSUED	

Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS

LEVEL SENSOR AMPLIFIER

SIZE	CODE IDENT NO.	DRAWING NO.
C	21351	183-07

SCALE NONE
SHEET 1 OF 1



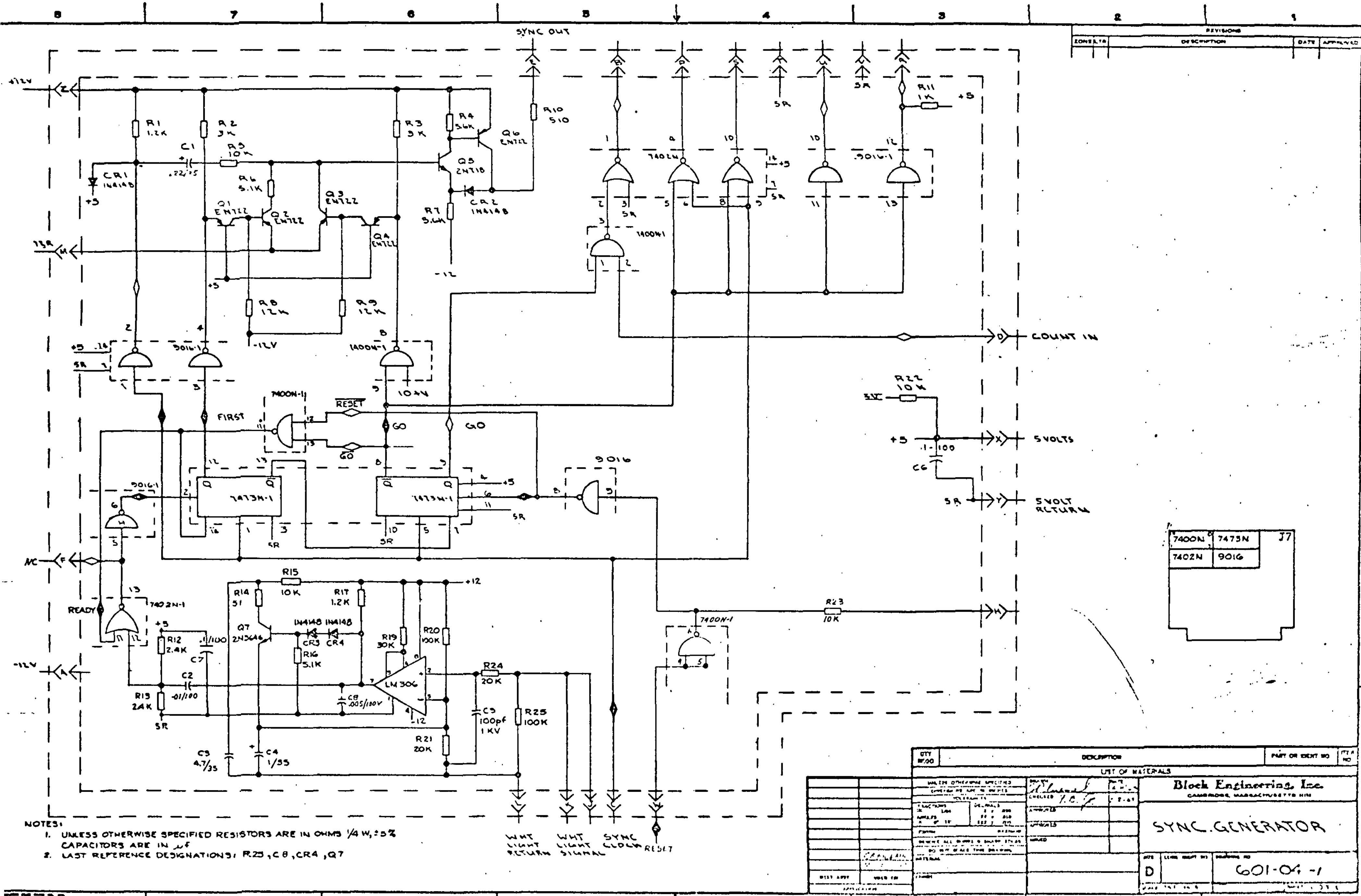
NOTES:
1. UNLESS OTHERWISE INDICATED:
RESISTANCES ARE IN OHMS, 1/4 W, 5%
CAPACITORS ARE IN μf
2. LAST REFERENCE DESIGNATION
R17, C5, Q2, CR3

LIST OF MATERIALS

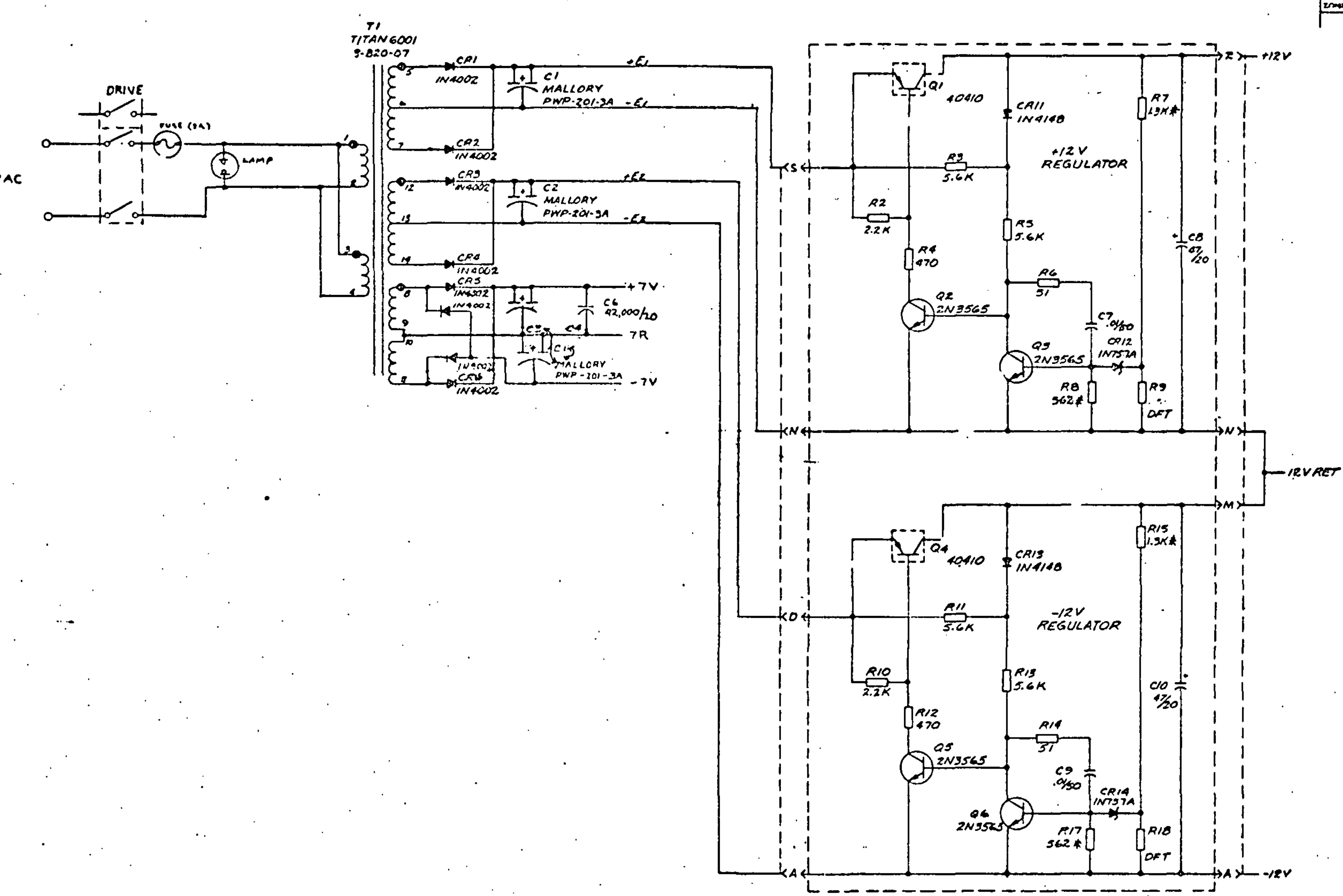
Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS

SWEEP RESET

SIZE D
DRAWING NO 601-02 - 2



NOTES:
1. UNLESS OTHERWISE SPECIFIED RESISTORS ARE IN OHMS 1/4 W, ±5%
CAPACITORS ARE IN µf
2. LAST REFERENCE DESIGNATIONS: R25, C8, CR4, Q7



NOTES: UNLESS OTHERWISE SPECIFIED

1. RESISTORS ARE IN OHMS, ±5%, ¼W;
   CAPACITORS ARE IN µf/RATED VOLTAGE.
2. ♦ DENOTES METAL FILM RESISTOR, ±1%, ⅛W
3. DFT - DETERMINE FINAL TEST
4. LAST REFERENCE DESIGNATIONS:
   C10, CR14, DS2, F2, Q6, R20, S2, T2
5. S1: HONEYWELL: 812TS1-10

QTY REQD	DESCRIPTION	PART OR IDENT NO	ITEM NO
	LIST OF MATERIALS		

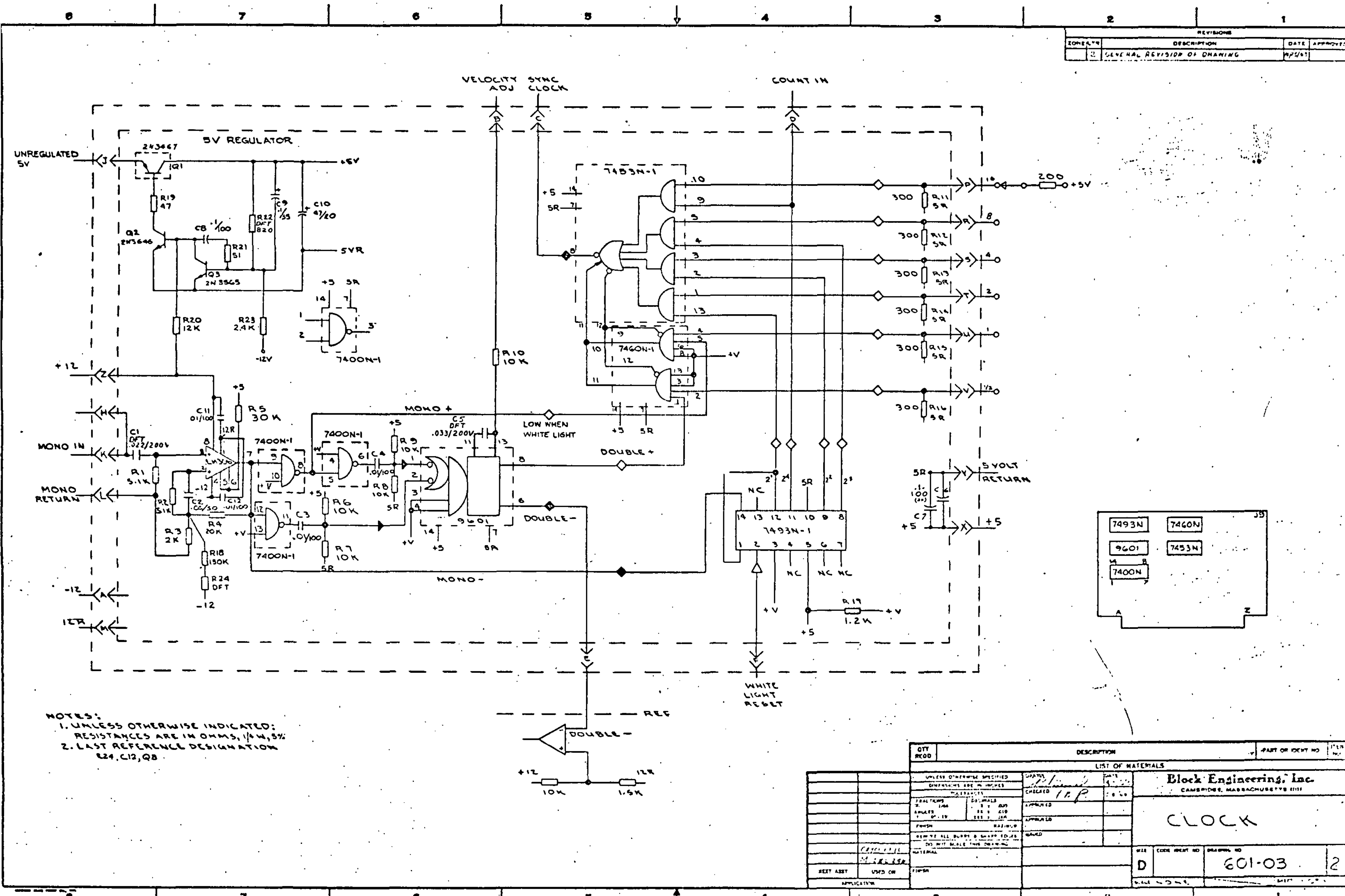
Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS

J15

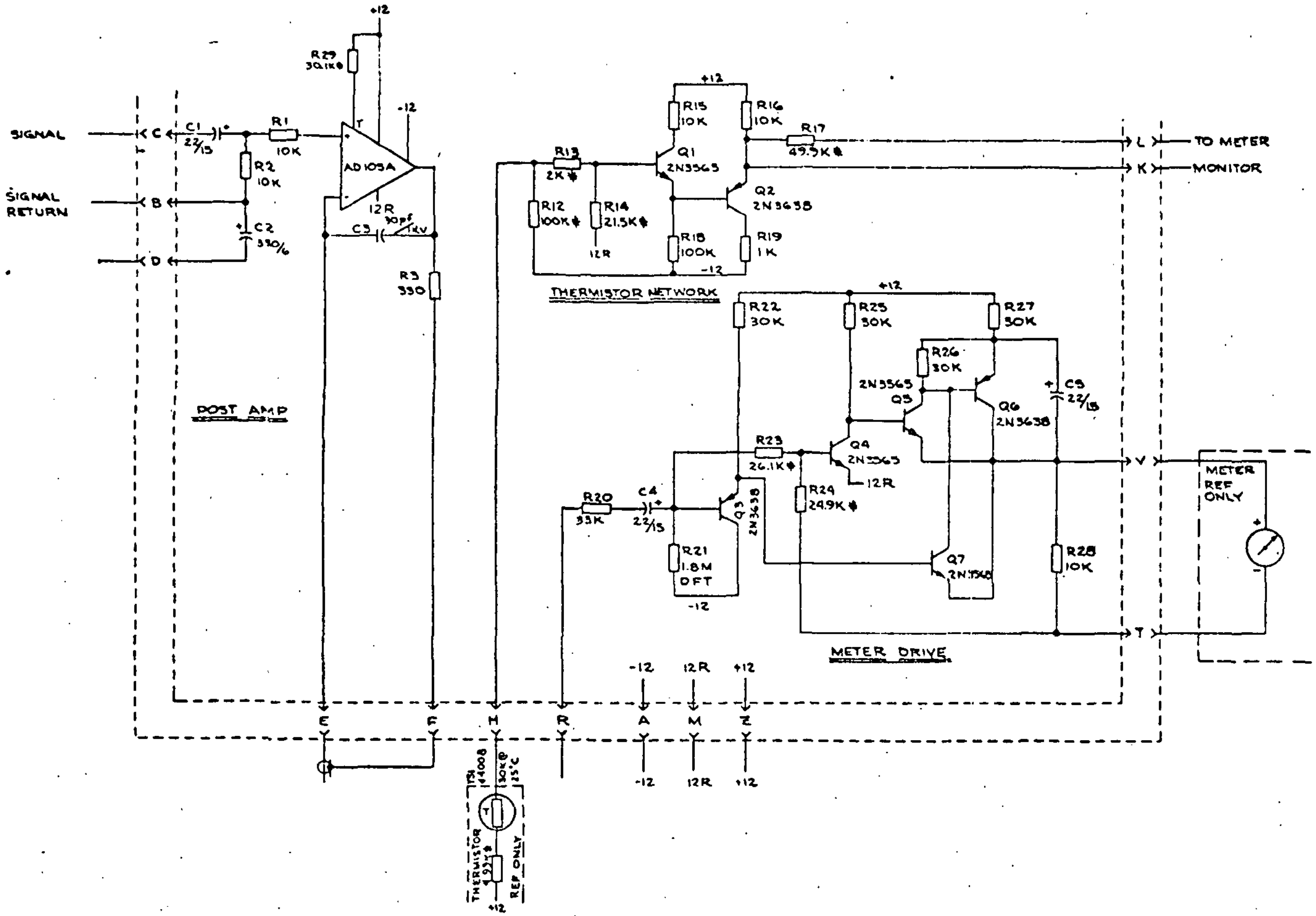
POWER SUPPLIES
& 12 VOLT REGULATORS

SIZE	CODE IDENT NO	DRAWING NO
D		280-48

SHEET 1 OF 1



5V REGULATOR
UNREGULATED 5V
2N3467
Q1
+5V
R19 47
Q2 2N3646
C8 1/100
R21 51
R22 DFT 820
C9 1/35
C10 47/20
5VR
Q3 2N3565
R20 12K
R23 2.4K
-12V
7400N-1
VELOCITY ADJ
SYNC CLOCK
COUNT IN
7453N-1
7460N-1
R10 10K
300
R11 5R
R12 5R
R13 5R
R14 5R
R15 5R
R16 5R
200
+5V
+12
MONO IN
MONO RETURN
C1 DFT .022/200V
R1 5.1K
R2 5.1K
R3 2K
C2 .05/50
R4 20K
R18 150K
R24 DFT
C11 .01/100
C12 .01/100
R5 30K
LM320
MONO +
MONO -
LOW WHEN WHITE LIGHT
DOUBLE +
DOUBLE -
C5 DFT .033/200V
R9 10K
R8 10K
C4 .01/100
C3 .01/100
R6 10K
R7 10K
9601
7493N-1
NC
R17 1.2K
5 VOLT RETURN
C6 1/100
C7
-12
12R
WHITE LIGHT RESET
REF
10K
1.5K
7493N
7460N
9601
7453N
7400N
NOTES:
1. UNLESS OTHERWISE INDICATED: RESISTANCES ARE IN OHMS, 1/4 W, 5%
2. LAST REFERENCE DESIGNATION R24, C12, Q8
REVISIONS
GENERAL REVISION OF DRAWING
LIST OF MATERIALS
Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS
CLOCK
D
601-03
2



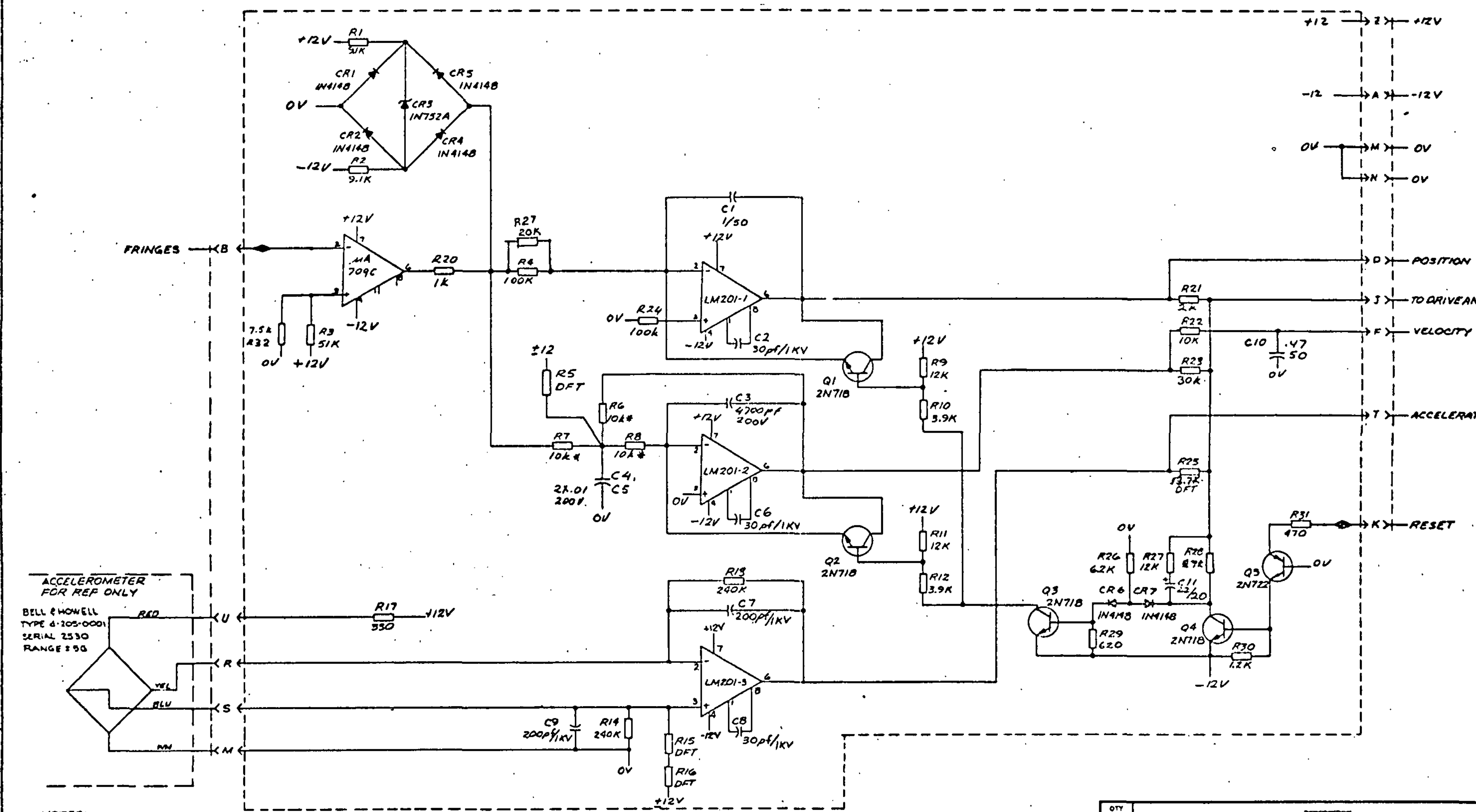
NOTES: UNLESS OTHERWISE SPECIFIED
1. RESISTORS ARE IN OHMS ±5%, 1/4W
2. CAPACITORS ARE IN µf/RATED VOLTAGE
3. ϕ INDICATES METAL FILM RESISTOR, ±1%, 1/8W
4. DFT - DETERMINE FINAL TEST
5. LAST REFERENCE DESIGNATIONS, R29, C5, Q7

LIST OF MATERIALS

Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS

POST AMP
THERM NETWORK
METER DRIVE

D 21351 121-35-1

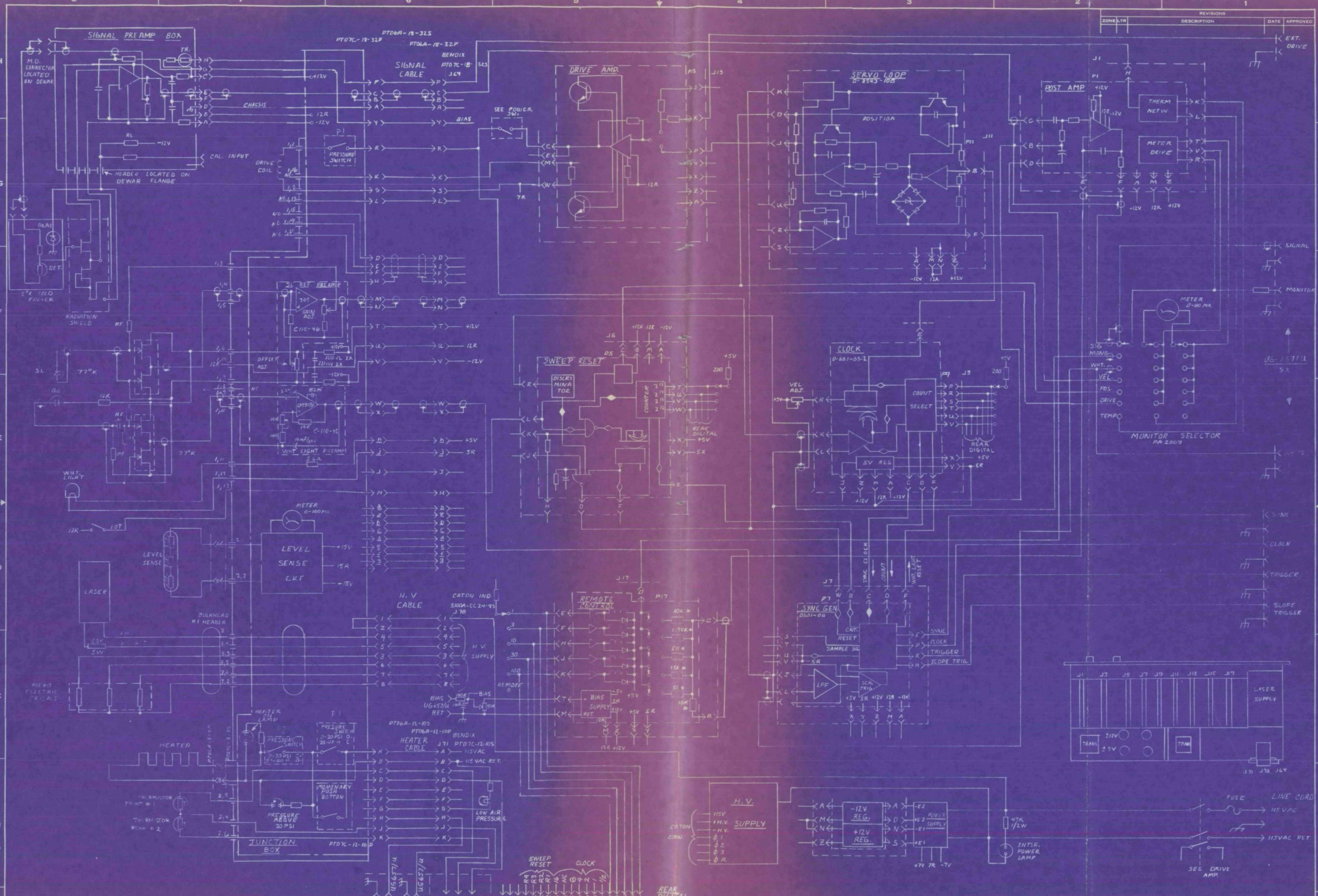


NOTES:
UNLESS OTHERWISE SPECIFIED
1. RESISTORS ARE IN OHMS, ±5%, 1/4 W
CAPACITORS ARE IN μF / RATED VOLTAGE
2. # INDICATES METAL FILM RESISTOR, 1/8W, ±1%
3. DFT DETERMINE FINAL TEST
4. LAST REFERENCE DESIGNATIONS:
R32 C11, CR7, Q5, LM201-2
5. REFERENCE DESIGNATIONS NOT USED: R18, R19,
R23

QTY REQD	DESCRIPTION	PART OR IDENT NO
	LIST OF MATERIALS	

Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS

SERVO LOOPS



QTY REQD	DESCRIPTION	PART OR IDENT NO.	ITEM NO.

LIST OF MATERIALS

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES
FRACTIONS ± 1/64 DECIMALS .X ± .020 .XX ± .010 .XXX ± .005
ANGLES ± 0° - 15'
FINISH MAXIMUM
REMOVE ALL BURRS & SHARP EDGES
DO NOT SCALE THIS DRAWING
MATERIAL
FINISH

NEXT ASST | USED ON: CRYOGENIC
APPLICATION

DRAWN | DATE
CHECKED
APPROVED HN 27 [illegible]
APPROVED
ISSUED

Block Engineering, Inc.
CAMBRIDGE, MASSACHUSETTS 02139

CRYOGENIC - INTERFEROMETER
WIRING DIAGRAM

SIZE E | CODE IDENT NO. | DRAWING NO. 920-22-0
SCALE | SHEET

APPENDIX A

DETECTOR INSTRUCTION MANUAL

SANTA BARBARA RESEARCH CENTER
A Subsidiary of Hughes Aircraft Company
75 COROMAR DRIVE, GOLETA, CALIFORNIA

INSTRUCTION MANUAL

LIQUID HELIUM DEWARS

MODELS 9144 AND 9145

June 1970

CONTENTS

LIQUID HELIUM DEWAR
SBRC MODELS 9144 and 9145

GENERAL DESCRIPTION

Santa Barbara Research Center Liquid Helium Dewars, Models 9144 and 9145, are designed for airborne low-vibration environment. Pertinent installation details are shown in Drawing 9592 for Model 9145 and Drawing 9598 for Model 9144.

The liquid helium (LHe) is shielded from radiation heat loading by a helium exhaust gas cooled shield. This dewar does not use liquid nitrogen (LN_2) for radiation shielding although LN_2 may be used to precool the reservoir, and thus conserve LHe.

Models 9144 and 9145 have a LHe capacity ranging from 0.4 to 1.5 liters. Helium consumption, after the dewar and shield temperatures stabilize, is typically 0.1 liquid liter per hour. From 0.1 to 0.2 liter of LHe is typically expended in initially stabilizing the temperature of the shield.

Cell data for the detector is recorded on the accompanying data sheets in the Appendix.

INSTALLATION

For installations of dewar proceed as follows:

1. Unpack the dewar and examine it for evidence of any physical damage. If the detector window is transparent, the detector and cold shield should be seen to be concentric with the window. This is true except for a side looking dewar where they will be seen low and off center. This is to compensate for shrinkage when the dewar is cooled.
2. Shake the dewar carefully to determine that no internal parts are loose. The assembly should have a "solid" feel. The dewar will withstand up to 100g shocks and although carefully packed, it can be damaged by careless handling.
3. If any damage is detected, enter a claim with the carrier and advise SBRC of the damage.

The dewar is shipped with a partial vacuum. Maintain a vacuum of 10^{-2} mm Hg or better at all times to avoid oxidation of highly polished internal surfaces and contamination of the detector surface.

The dewar is designed for mounting on the front flange. The mounting hole pattern is shown in the outline and mounting drawing. (See Appendix) Note that the window is recessed in its mounting plate to prevent damage when the dewar is placed on a flat surface.

Detector leads terminate in a Microdot 51-232 coaxial receptacle mounted on the case. Low-noise cable, Part No. 250-3804, and connector, Part No. 32-21, may be purchased from Microdot Incorporated, 220 Pasadena Avenue, South Pasadena, California, 91030. These parts are used to connect the detector to a preamplifier. The optimum bias power for each detector is shown in the data sheet in the appendix. Detectors over 3mm in size will generally have one detector lead grounded to the dewar unless otherwise ordered.

OPERATION

Preparation for Filling

Several filling methods are available depending on 1) the method of operation, 2) the quantity of LHe available, and 3) the vacuum attainable. If the dewar is easily removable from its associated equipment it is preferable to remove it during filling. Repumping of the dewar before each use is not necessary, but may be desirable as will be discussed later.

A combination mechanical forepump and diffusion pump system are generally required to obtain a good insulating vacuum. Connection to the vacuum pump may be made with a rubber vacuum hose.

Do not attempt to lift the evacuation stopper until the vacuum pump has equalized the pressure, then life carefully to prevent loss of the O-ring on the stopper. A permanent type of evacuation fitting is standard. The dewar is fitted with a No. 40081 permanent fitting. To open it, extend the rod past the guide pin and rotate to hold the evacuation fitting open.

To obtain a recommended starting vacuum of 1×10^{-5} Torr (mm Hg) or better, proceed as follows:

1. Pump the flask with the diffusion pump system for 1 hour or more.
2. Use an LN_2 or CO_2 cooled trap in the vacuum line to protect the dewar from contamination from the pump back streaming.
3. Close the evacuation stopper very slowly; hold the stopper in place until the pressure is returned to atmospheric above the stopper.

The dewar may be operated with starting pressures higher than 10^{-5} Torr if required. At least 10^{-4} Torr is required if the flask is to be pre-cooled with LN_2. Pressures higher than 10^{-4} Torr do not provide sufficient insulating vacuum for LN_2 pre-cooling. If a mechanical forepump is the only pump available, use an LN_2 or CO_2 cooled trap in the vacuum line to protect the dewar from contamination from the pump back streaming.

Successful operation is possible without initial vacuum in the dewar; however, gasses may condense on the detector and blind it. Contamination of the detector and dewar can also be caused by operating without initial vacuum; therefore, it is not normally recommended.

Pre-Cooling the Dewar

To pre-cool the dewar, proceed as follows:

1. Remove the entire teflon neck plug assembly while filling.
2. Pre-chill the dewar by filling with LN_2. This conserves LHe because about 95% of the heat is removed from the inner dewar by pre-cooling to LN_2 temperature.
3. Pour out the LN_2 immediately and fill the dewar with LHe.

NOTE

Maximum partial shield pre-cooling is achieved in about 1 hour. Additional pre-cooling (keeping the flask filled to the neck) or pre-cooling for up to 2 hours will produce a slight additional running time. Pre-cooling the shield lowers the initial helium boil-off rate, saving from 0.1 to 0.2 liter of helium and extending the running time by 1 to 2 hours.

4. If it is inconvenient to pour or pump the LN_2 out of the dewar, pre-chill the inner dewar before filling with LHe, or pour 50 grams (63 cc) of LN_2 into the dewar, using a paper funnel. If a glass or metal funnel is used, the funnel must be pre-chilled or allowance made for the LN_2 evaporated by the funnel. This amount will boil off in approximately 5 minutes, at which time the LHe may be added.

Filling the Dewar

A suitable vacuum insulated transfer line must be used when transferring liquid helium. A helium transfer line is recommended with an extension 1/8 to 1/4 inch in diameter and at least 6 inches in length to enter the dewar neck. In long dewars or dewars with extended snouts, the fill line should extend to within a few inches of the dewar bottom. Transfer lines are manufactured by the Linde Company, 270 Park Avenue, New York, New York; Sulfrian Cryogenics, Inc., 391 East Inman Avenue, Rahway, New Jersey; and Hofman Laboratories, Inc., 225 Parkhurst Street, Newark, New Jersey. The Sulfrian

Drawing No. A-6222-1 Hofman Bulletin 3007 are suitable types. The manufacturer will need to know the dimensions of the supply dewar. The LHe fill line is usually available through the supplier of LHe. A supply of gaseous helium at about 1 to 2 psi, which may be provided by a cylinder of helium fitted with a pressure regulator is usually required to transfer from the supply dewar. Slow rates of transfer of liquid helium are most economical when filling.

To fill the dewar proceed as follows:

1. Pre-cool the transfer line by slowly increasing the pressure on the supply dewar. To prevent the warm helium gas from re-warming the pre-chilled dewar do not insert the fill line until the issuing gas is near LN_2 temperature.
2. Insert the fill line so that only 1/2 inch of uninsulated line is outside the dewar neck. Detector resistance may be measured as an indication of the moment that LHe is entering the dewar. A pronounced increase in the vapor effluent indicates that the reservoir if filled with liquid helium.
3. Quickly lower the pressure on the supply dewar and remove the fill line from the detector dewar neck when the dewar is full.
4. Install the teflon plug and stopper to provide proper shield cooling.

Transfer losses will be about 1 or 2 liters and may be as high as 5 liters or more depending on the filling techniques. With low filling pressure (1/2 to 1 psi) the amount of LHe required to fill the dewar with no initial vacuum and a 5-minute LN_2 pre-chill is the same as with a good vacuum and a 2-hour pre-chill. Pre-cooling of the radiation shield will lower the initial boil-off rate and provide 1 to 2 hours of additional running time.

To further extend the running time, top off the LHe 1 hour after filling. Pre-cooling of the transfer line, and slow topping off, is essential to avoid blowing out the LHe in the flask. The maximum operating time is attained when the shield is cooled to equilibrium and the boil-off rate is stabilized, which occurs from 1 to 2 hours after filling with LHe regardless of the previous dewar and shield precooling by LN_2. The initial helium gas boil-off rate may be as high as 20 liters per minute or as low as 3 liters per minute, depending on the pre-cooling. The equilibrium boil-off rate is typically less than 1 gaseous liter per minute.

GENERAL OPERATIONS NOTES

The plastic neck plug and its stopper are designed to assist in the heat transfer from the flask inner neck and radiation shield to the exhaust helium gas. The plug must be in place in the neck for efficient operation. It is desirable to pre-cool the plug in LN_2 before emplacement. The plug should be loose in the neck when helium is in the flask. Additional protection against helium pressure build up is afforded by the silicone rubber stopper in the plug. Push in only tight enough to prevent leakage of exhaust helium. Do not force. If relief valve, Part No. 9773, is used, the metal and plastic central plug must be in place if proper heat transfer is to take place.

The cryopumping action of the LHe will produce a vacuum of 10^{-6} Torr or better in the flask. The pressure is principally due to hydrogen which has a vapor pressure of 10-6 Torr at 4.2 °K. The hydrogen outgasses from the metal parts of the dewar. (Nitrogen is pumped to below 10^{-30} Torr). The low pressure promotes outgassing of warm portions of the dewar. When the helium is exhausted, the pressure in the vacuum space will rise to a pressure dependent on the previous vacuum history and cleanliness of the dewar. With a relatively new dewar, this vacuum is often not sufficient to provide the insulation required for the flask to hold LN_2. The residual vacuum will improve with use and repumping.

MAINTENANCE

Periodic vacuum pumping is required to protect the detector and remove residual helium gas. Since the LHe freezes out all other gasses, it is the only gas which can spoil the insulating vacuum. An air leak of 10^{-3} std cc per second will reduce the running time by 1%. A helium leak of 10^{-7} std cc per second will spoil the insulating vacuum in 1 hour. Thus, it is apparent that a relatively large air leak is tolerable provided no helium enters with the air.

Vacuum Leak

If a vacuum leak is suspected, proceed as follows:

1. Use a helium leak detector to locate the leak.
2. If O-rings are faulty, replace with new O-rings of butyl rubber having a hardness of 70 durometer.
3. Lubricate all O-rings with a very light film of Apiezon grease, preferably or Dow Corning silicone vacuum grease.
4. Use all care to prevent the accumulation of water in the inner dewar. Water freezing in the inner dewar joints can expand the joints and cause a leak.

SAFETY PRECAUTIONS

WARNING

Exercise caution when using any liquefied gas. The extremely low-temperature liquids can cause injury to the skin and eyes. Use gloves and face shield during liquid transfer operation.

During the time that the dewar contains liquid helium, the plastic plug in the neck must be loose and free to move. Take proper care to see that water does not collect in such a manner that the plug becomes frozen in place. Upon changes in altitude, use caution to see that air is not drawn into the dewar neck. The low temperature will solidify the air, thus plugging the neck - a potentially harzardous situation. A rate of increase of ambient pressure in excess of 0.2 psi per minute (or 1,000 feet-per-minute altitude loss) is sufficient to draw air into the dewar. The plastic neck plug with its silicone rubber stopper provides a measure of protection against this hazard. If, however, the neck becomes plugged, the frozen air plug must be removed forcibly by ramming with a metal rod. Relief valve, Part No. 9773, is recommended for airborne applications. Its check-valve action prevents ingestion of air.

A safety pressure-relief valve is incorporated in the evacuation fitting. Its function is to relieve any pressure build-up in the normally evacuated space. Such a pressure build-up is possible when the dewar warms up, if a leak has permitted the helium to cryopump an appreciable quantity of gas or if the helium container develops a leak.

The LHe will condense gasses on the inner flask and produce a high vacuum sufficient for successful operation. With starting pressures greater than 10^{-2} mm Hg (or if there is a vacuum leak during operation), the insulating vacuum will be lost during warm up, and the increased heat transfer to the helium flask will produce a rapid warming of the remaining helium. The sudden expansion of helium gas may blow the plug out of the neck amidst a cloud of very cold gas. Though no damage to the flask will be encountered by this operation, it is suggested that precautions be taken to avoid injury from the plug or cold gas.

WARNING

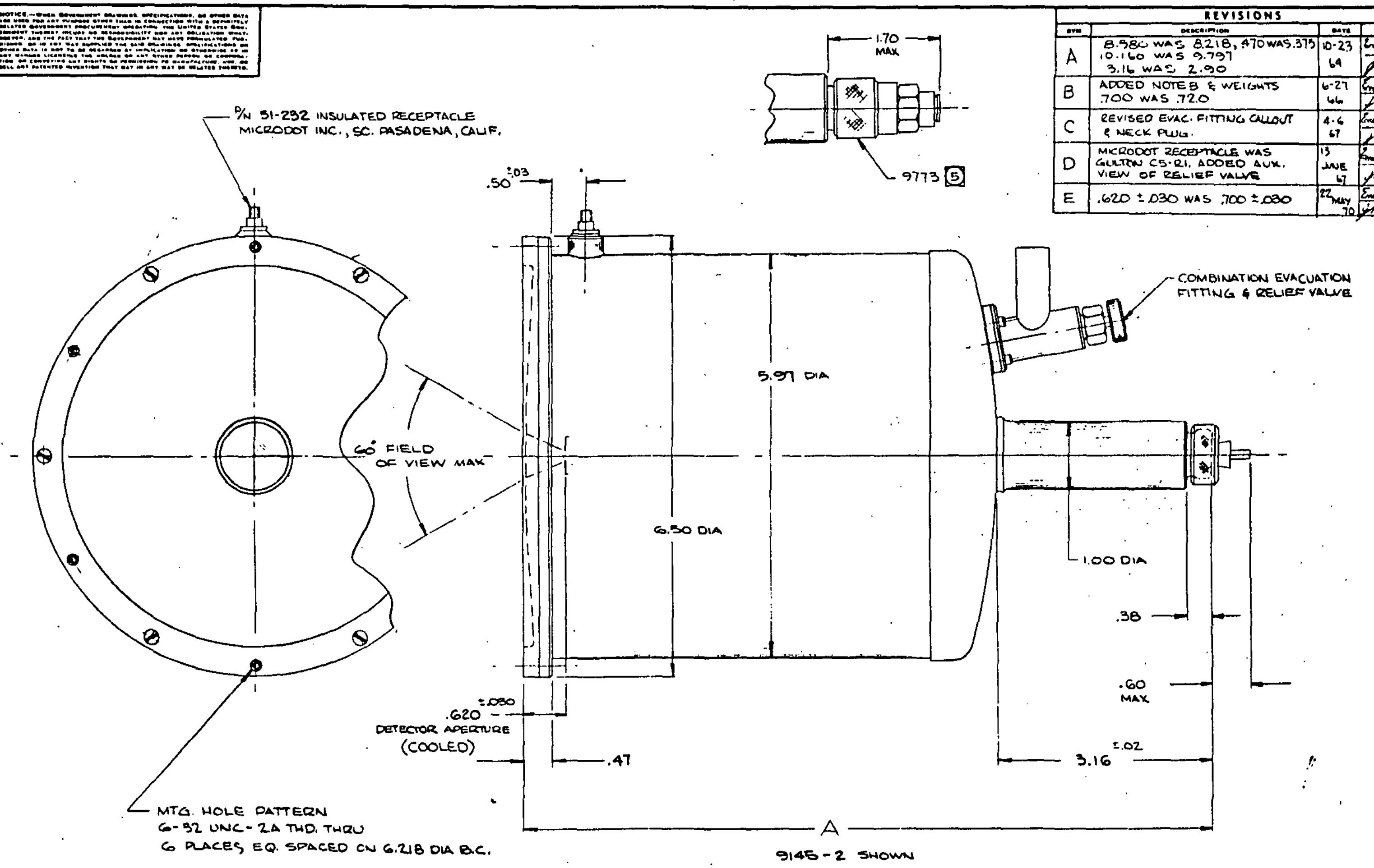
Do not lean over the flask during operation or warm up.

APPENDIX

INSTALLATION AND PARTS DRAWINGS

DETECTOR DATA SHEETS

SYM	DESCRIPTION	DATE	APPROVAL
A	8.980 WAS 8.218, .470 WAS .375 10.160 WAS 9.797 3.16 WAS 2.90	10-23 64	
B	ADDED NOTE 5 & WEIGHTS .700 WAS .720	6-27 66	
C	REVISED EVAC. FITTING CALLOUT & NECK PLUG.	4-6 67	
D	MICRODOT RECEPTACLE WAS GULTON C5-21. ADDED AUX. VIEW OF RELIEF VALVE	13 JUNE 67	
E	.620 ± .030 WAS .700 ± .030	22 MAY 70	



TABULATION			
PART NO	A DIM ±.040	WEIGHT	STD HOLD TIME
9145-1	8.580	4.62 LBS	8 HOURS
9145-2	10.160	5.41 LBS	12 HOURS

5. RELIEF VALVE TO BE USED WHEN EXTREME BAROMETRIC PRESSURE CHANGES ARE ANTICIPATED.
4. STANDARD DETECTOR SENSITIVE AREA .5 MM TO 3 MM DIAMETER
3. DETECTOR LEAD STRAY CAPACITY 10 PICOFARAD MAX.
2. DETECTOR TO HAVE OPTIMUM BIAS OF POSITIVE POLARITY ON CENTER CONDUCTOR OF CONNECTOR.
1. FOR ASSY SEE SBRC DWG. 9145

NOTES: UNLESS OTHERWISE SPECIFIED.

APPLICATION | QTY REQD

SURFACE FINISH √ ALL OVER EXCEPT AS NOTED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± DECIMALS ±.01 ANGLES ±

MATERIAL —
HEAT TREAT —
FINISH —

OUTLINE & MTG-
HE DEWAR
NO. 9145

SANTA BARBARA RESEARCH CENTER
SANTA BARBARA MUNICIPAL AIRPORT
GOLETA, CALIFORNIA

9592

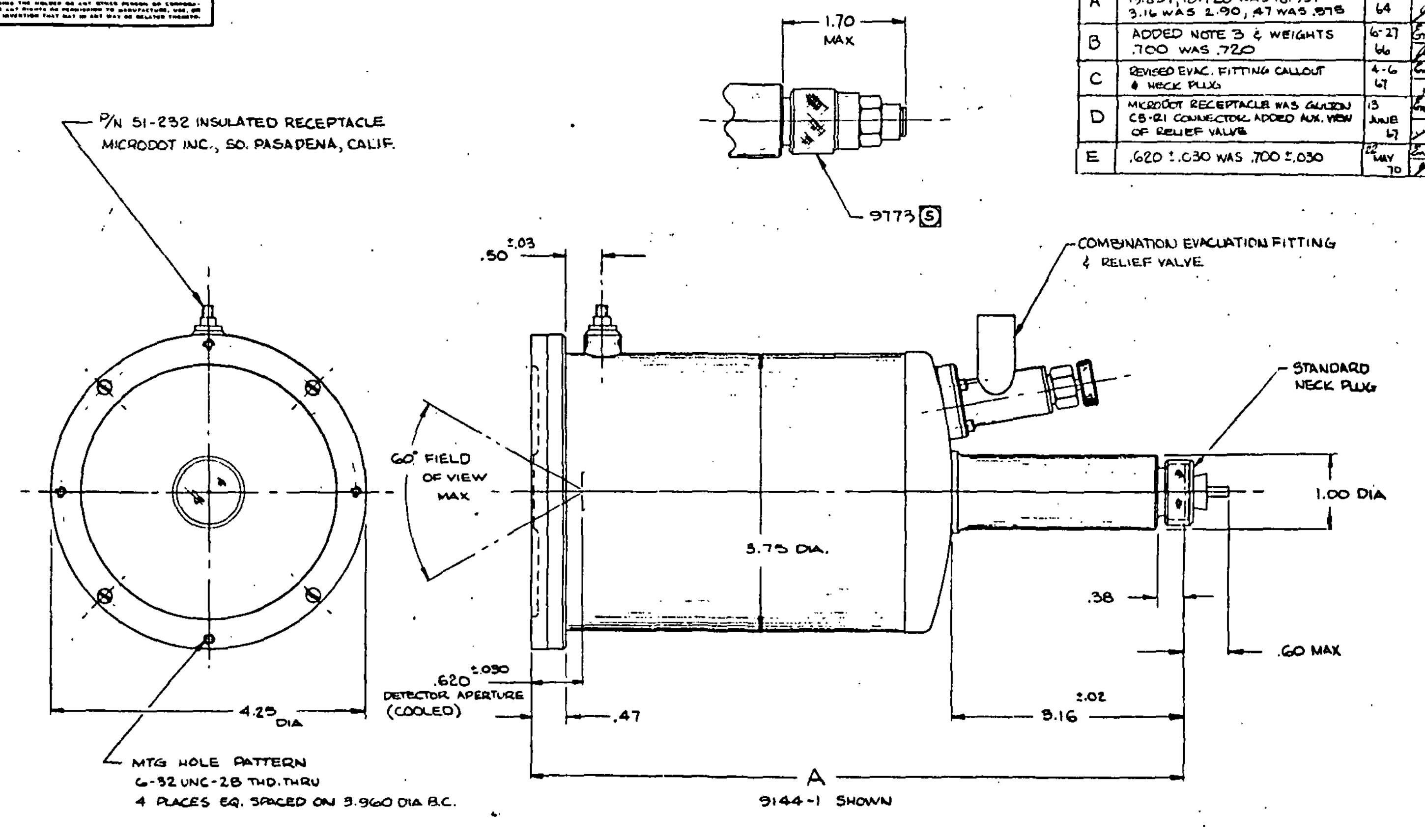
CODE IDENT 11323

SCALE 1/1

9592 E

NOTICE.—When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL
A	8.848 WAS 8.487, 14.220 WAS 13.857, 18.720 WAS 18.357, 3.16 WAS 2.90, .47 WAS .578	11-13 64	
B	ADDED NOTE 3 & WEIGHTS .700 WAS .720	6-27 66	
C	REVISED EVAC. FITTING CALLOUT & NECK PLUG	4-6 67	
D	MICRODOT RECEPTACLE WAS GALLSON CB-21 CONNECTOR, ADDED AUX. VIEW OF RELIEF VALVE	13 JUNE 67	
E	.620 ±.030 WAS .700 ±.030	22 MAY 70	



TABULATION			
PART NO.	A DIM ±.040	WEIGHT	STD HOLD TIME
9144-1	8.848	2.56 LBS	3 HOURS
9144-2	14.220	3.90 LBS	8 HOURS

5. RELIEF VALVE TO BE USED WHEN EXTREME BAROMETRIC PRESSURE CHANGES ARE ANTICIPATED.

4. STANDARD DETECTOR SENSITIVE AREA .5 MM TO 3 MM DIAMETER

3. DETECTOR LEAD STRAY CAPACITY 10 PICOFARAD MAX.

2. DETECTOR TO HAVE OPTIMUM BIAS OF POSITIVE POLARITY ON CENTER CONDUCTOR OF CONNECTOR.

1. FOR ASSY SEE SBRC DWG 9144

NOTES: UNLESS OTHERWISE SPECIFIED.

APPLICATION: NEXT ASSY | USED ON — QTY REQD: NEXT ASSY | FINAL ASSY

SURFACE FINISH √ ALL OVER EXCEPT AS NOTED

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS ± DECIMALS ±.01 ANGLES ±

MATERIAL —

HEAT TREAT —

FINISH —

APPROVED / APPROVED / DESIGN / CHECKED / DRAWN — SIGNATURE — DATE

OUTLINE & MTG. - HE DEWAR NO. 9144

SCALE 1/1

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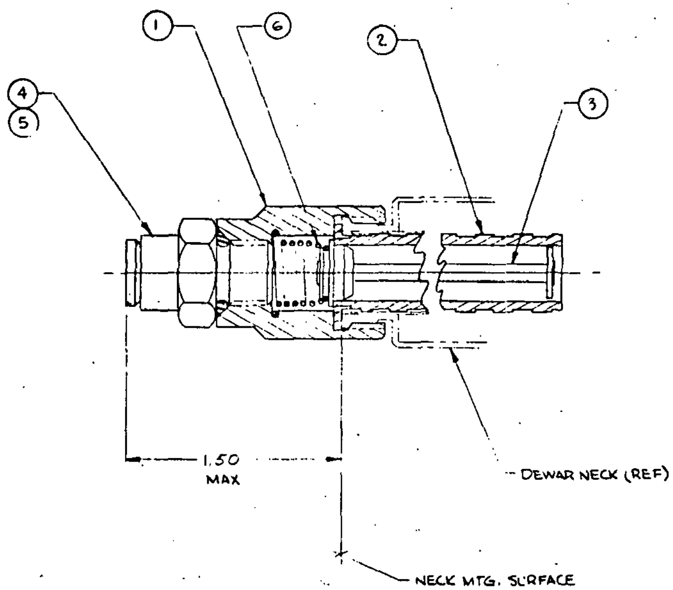
SANTA BARBARA MUNICIPAL AIRPORT
GOLETA, CALIFORNIA

9598

CODE IDENT 11323 SHEET OF

9598 REV E

MODEL EFFECTIVITY	SYM	REVISIONS DESCRIPTION	DATE	APPROVED
	A	1.50 MAX WAS 1.30 MAX.; REVISED VIEW TO MATCH DETAILS; ADDED ITEM 6	16 NOV 67	



QTY REQD	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	ITEM NO
1	41827	SPRING, VALVE	6
1		O-RING, PARKER NO. Z-12, COMP NO. 5418-6 [2]	5
1		VALVE, RELIEF - CIRCLE SEAL NO. 524A-4D-2 [1]	4
1	9786	STOPPER ASSY	3
1	40141	PLUG, TEFLON	2
1	9764	ADAPTER, VALVE	1

LIST OF MATERIAL

[2] MAY BE PURCHASED FROM PARKER SEAL CO., CULVER CITY, CALIF.

[1] MAY BE PURCHASED FROM JAMES, POND & CLARK, PASADENA, CALIF.

NOTES: UNLESS OTHERWISE SPECIFIED

PART NO	NEXT ASSY	USED ON
BSC	9144	9145
BSC	9145	9144

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON

FRACTIONS	DECIMALS .XX	DECIMALS .XXX	ANGLES
± -	± -	± -	± -

MATERIAL: SEE L/M

STOCK SIZE (REF)

RELEASE DATE: 1966

PREPARED: 2-18-66

CHECKED

APPROVED

APPROVED

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GOLETA, CALIFORNIA

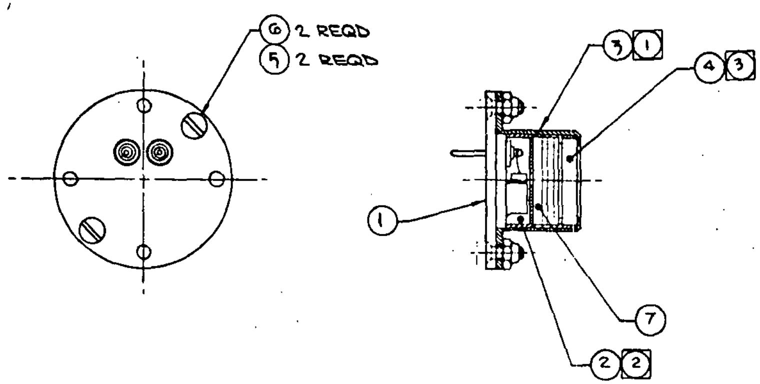
TITLE: RELIEF VALVE ASSY (INSTALLATION)

CODE IDENT NO: 11323 | SIZE: C | NUMBER: 9773

SCALE 2/1 | SHEET

PROJECT 1238

9773 A



3. WHEN FILTER IS REQUIRED USE P/N 40661 FILTER IN PLACE OF ITEM 4 SPACER.

2. PROPER DASH NUMBER OF MASK TO BE DETERMINED FROM SIZE OF SENSITIVE AREA OF DETECTOR.

1. PROPER DASH NUMBER OF SHIELD TO BE DETERMINED FROM SIZE OF DETECTOR & FIELD OF VIEW REQUIREMENT.

NOTES: UNLESS OTHERWISE SPECIFIED

QTY REQD	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	ITEM NO
1	9348	SPRING, FILTER RETAINER	7
2	COML	SCREW FL HD CRES 2-56UNC-3A x 1/4 LG	6
2	COML	NUT, NO. 50FM-256 STANDARD PRESSED STEEL, JENKINGTOWN, PENN.	5
1	41004	SPACER	4
1	9346	CELL SHIELD	3
1	9347	MASK	2
1	40986	DETECTOR ASSY	1

LIST OF MATERIAL

PART NO	NEXT ASSY	USED ON
BSC	9145 / 9144	9145 / 9144

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON

FRACTIONS	DECIMALS .XX	DECIMALS .XXX	ANGLES
± —	± —	± —	± —

MATERIAL: SEE LIST OF MATL

STOCK SIZE (REF)

RELEASE DATE 03 MAY 1967

PREPARED A. Harris 13 MAR 67

CHECKED Emins 5-2-67

APPROVED [signature] 5/3/67

APPROVED

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A Subsidiary of Hughes Aircraft Company
GOLETA, CALIFORNIA

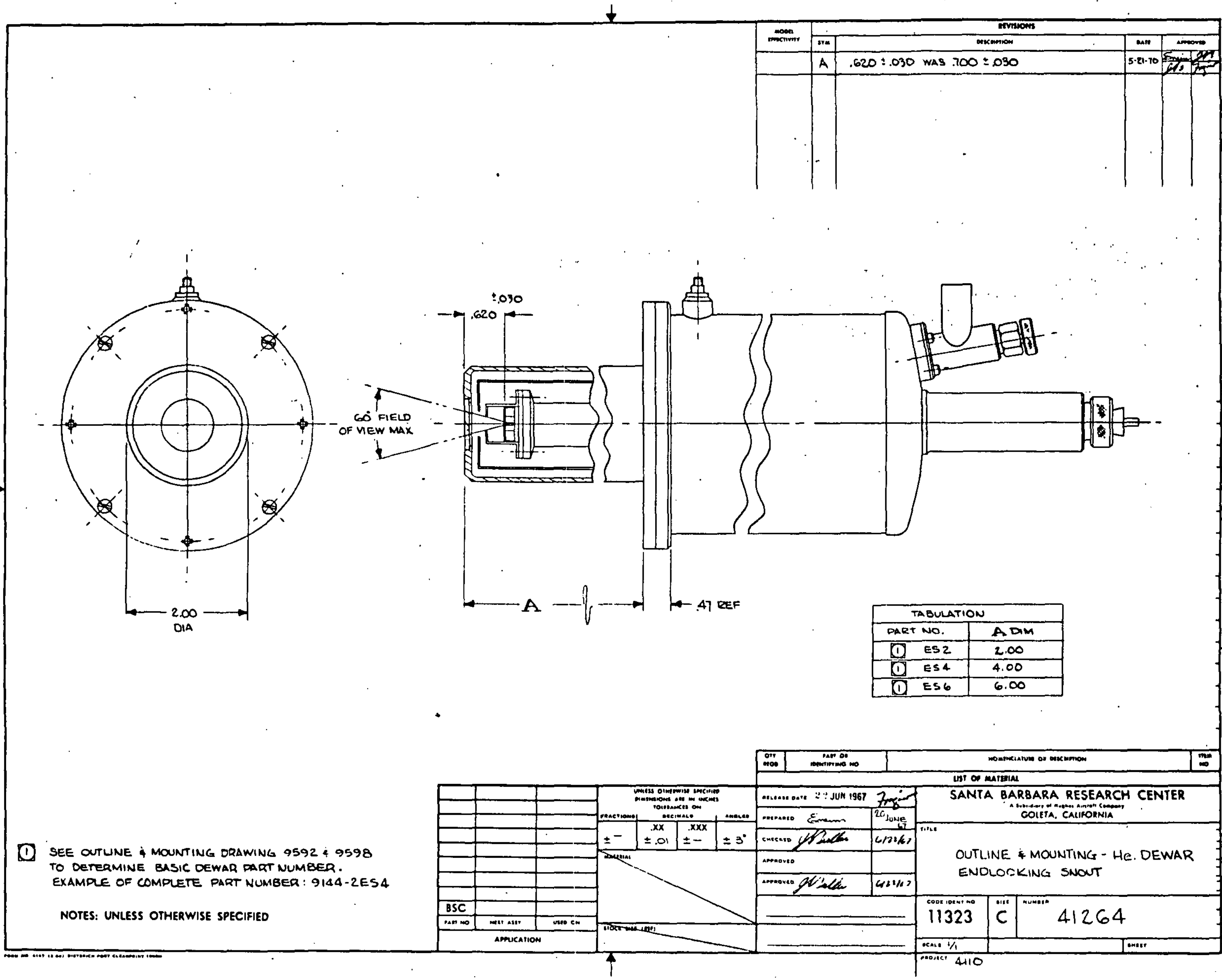
TITLE: CELL PACKAGE, PLUG-IN

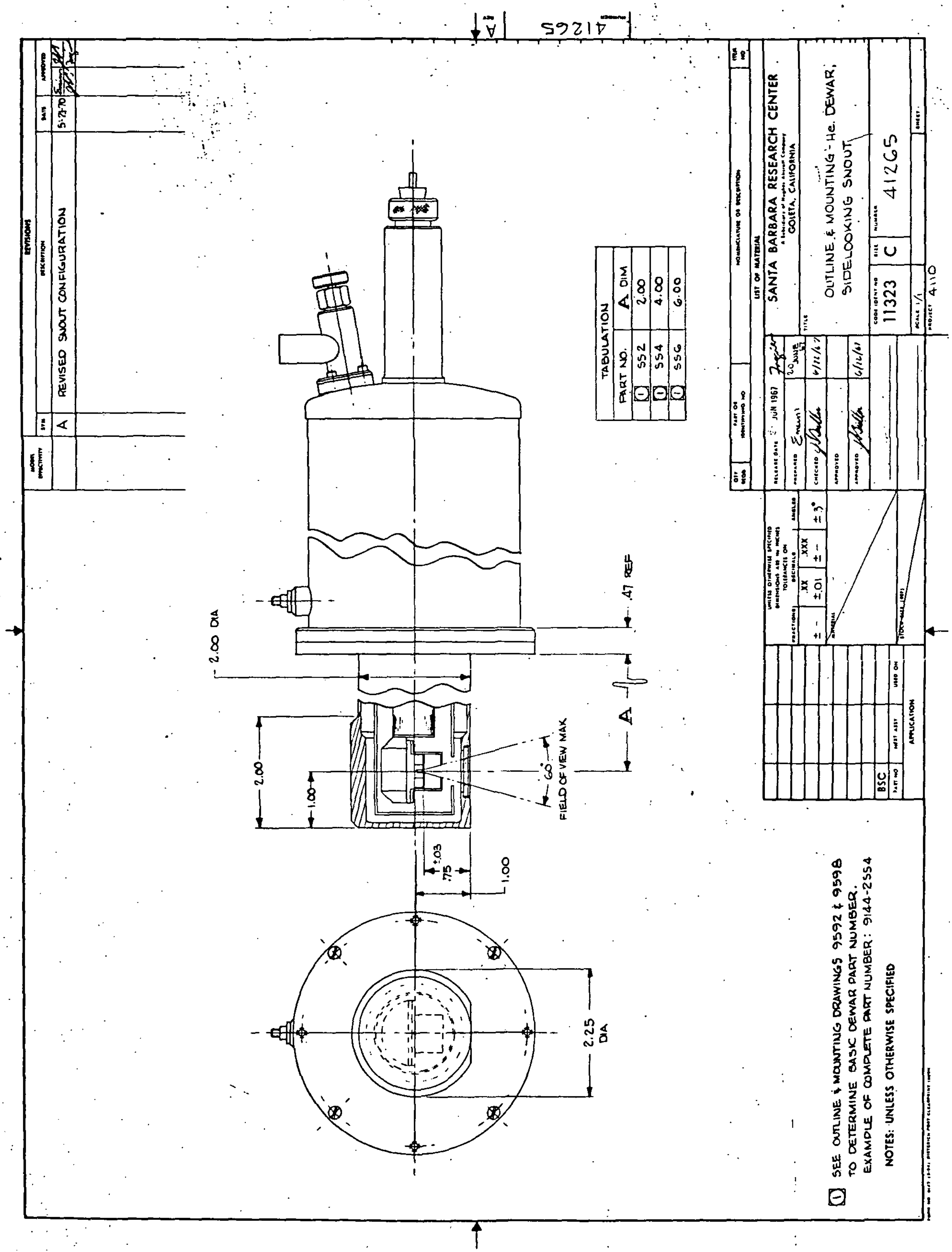
CODE IDENT NO 11323 | SIZE C | NUMBER 40987

SCALE 2/1 | SHEET

PROJECT

40987


REVISIONS
A .620 ± .030 WAS .700 ± .030 5-21-70
±.030
.620
60° FIELD OF VIEW MAX
2.00 DIA
A
.47 REF
TABULATION
PART NO. A DIM
1 ES2 2.00
1 ES4 4.00
1 ES6 6.00
1 SEE OUTLINE & MOUNTING DRAWING 9592 & 9598 TO DETERMINE BASIC DEWAR PART NUMBER. EXAMPLE OF COMPLETE PART NUMBER: 9144-2ES4
NOTES: UNLESS OTHERWISE SPECIFIED
BSC
APPLICATION
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON
FRACTIONS ± —
DECIMALS .XX ± .01 .XXX ± —
ANGLES ± 3°
LIST OF MATERIAL
RELEASE DATE 22 JUN 1967
SANTA BARBARA RESEARCH CENTER
A Subsidiary of Hughes Aircraft Company
GOLETA, CALIFORNIA
OUTLINE & MOUNTING - He. DEWAR ENDLOCKING SNOUT
CODE IDENT NO 11323
SIZE C
NUMBER 41264
SCALE 1/1
PROJECT 410
41264
A


REVISIONS
A REVISED SNOUT CONFIGURATION 5-12-70
TABULATION
PART NO. A DIM
552 2.00
554 4.00
556 6.00
2.00 DIA
.47 REF
A
2.80
1.00
60°
FIELD OF VIEW MAX
±.03
.75
1.00
2.25 DIA
SANTA BARBARA RESEARCH CENTER
GOLETA, CALIFORNIA
LIST OF MATERIAL
RELEASE DATE JUN 1967
OUTLINE & MOUNTING - He. DEWAR, SIDELOOKING SNOUT
11323
C
41265
SCALE 1/1
PROJECT 4110
±.01
±3°
BSC
APPLICATION
1 SEE OUTLINE & MOUNTING DRAWINGS 9592 & 9598 TO DETERMINE BASIC DEWAR PART NUMBER.
EXAMPLE OF COMPLETE PART NUMBER: 9144-2554
NOTES: UNLESS OTHERWISE SPECIFIED

APPENDIX B

TAPE RECORDING OF ANALOG OUTPUTS

Section 1

1.0 Instrumentation

The recording of the analog outputs from the spectrometer requires the use of the interferometer optical head, the interferometer spectrometer controller chassis and an analog tape recorder of sufficient bandwidth as dictated by Tables 1 and 2.

1.1 Data to Be Recorded

Two outputs from the spectrometer are to be recorded; namely the signal (or interferogram and the composite sync (the combined trigger and clock). These waveforms may be obtained at the labeled test points on the controller front panel.

1.2 Required Bandwidth

The bandwidth requirements for the analog tape recorder are determined by the particular instrument being used. The table below lists high frequency requirements for both signal and sync assuming that the spectrometer is running with a retardation rate which produces a 10 kHz mono-frequency. (This can be examined via the monitor output on the controller chassis front panel.) Mono-frequencies other than 10 kHz are reflected in a proportional change in the frequencies listed, e.g. a 5 kHz mono-frequency would produce a 10 kHz sync frequency for sampling interval, 1/2.

Table No. 1

Sampling Interval	Highest Frequency Sync	Highest Frequency Signal
1/2	20 kHz	10 kHz
1	10 kHz	5 kHz
2	5 kHz	2500 Hz
4	2500 Hz	1250 Hz
8	1250 Hz	625 Hz
16	625 Hz	312 Hz

NOTE: The above table is valid only for a 10 kHz mono signal.

The low frequency response is not as easily determined since it is related to both the mono-frequency and to the longest wavelength (i.e. lowest optical frequency) of interest. Again, for the case of a 10 kHz mono-frequency, the following table is presented.

Table No. 2

Longest Wavelength (μ)	Lowest Signal Frequency
1.25	5000 Hz
2.5	2500 Hz
5	1250 Hz
10	625 Hz
20	312 Hz
30	200 Hz
40	150 Hz

By using the above tables one can determine the necessary frequency response for the analog tape recorder.

Example 1: A typical InSb application -
Mono-frequency = 10 kHz
Shortest wavelength of interest = 2 microns
Longest wavelength of interest = 6 microns

Since the shortest wavelength of interest is two microns, the required sampling interval is 0.6328μ or sample 1, i.e.

$$\frac{2\mu}{2} \quad N(0.6328\mu)$$

for N = 1 where N is the sampling interval. From Table 1, it is seen that the sync channel must have a 10 kHz response and the signal channel a high frequency response of 5 kHz. The longest wavelength of six microns requires response to approximately 1 kHz (from Table No. 2).

Example 2: A typical TGS application -
Mono-frequency = 10 kHz
Shortest wavelength of interest ≐ 2.6 microns
Longest wavelength of interest = 25 microns

By the same reasoning as in Example 1, the sync channel requires a 5 kHz response while the signal requires a bandwidth of approximately 200 to 2500 Hz.

Section 2

2.0 Use of the Analog Tape Recorder

When using a multiple track recorder, only one precaution is urged. The two channels allocated to the interferometer should be chosen so as to lie on the same head stack and as near to each other as possible. In an IRIG standard configuration machine with dual record head stacks, the odd numbered channels are on one stack and the even numbered channels are on the second stack. The tracks chosen on an IRIG machine would thus be two even or odd numbered tracks. The effect of this selection is to minimize the phase error between the recorded sync and signal. The tracks may be either FM or direct provided they have the necessary bandwidth.

The tape recorder channels should be aligned as outlined in the instruction manual for the particular machine being used. The channels should be aligned for a normal full scale input of 6 volts peak to peak for the sync (at the frequency of the sync to be recorded) and for a 20 volt peak to peak signal level input (at a frequency approximately in the center of the frequency response region) for the signal channel.

NOTE: If the targets being observed are of such a low intensity that the spectrometer signal output is always less than a 20 volt peak to peak value in the highest gain position, it is advisable to set the signal channel on the recorder for a smaller peak to peak value (as determined from observation of the target) in order to minimize the effect of the tape recorder noise*. A word of caution in this regard is appropriate. Since the signal waveform (interferogram) is likely to be unsymmetric about zero volts, the peak to peak value for which the tape recorder is adjusted should be twice the largest zero to peak excursion in the interferogram.

---

* One should establish the residual tape recording amplifier and tape noise in terms of volts equivalent at the input in order that the full dynamic range of the tape system be exploited at all times.

APPENDIX C

MODEL DT-512 PLAYBACK CONSOLE

1.0 General Description

The Block Engineering, Inc. Playback Console is designed to enhance the versatility of Digilab's FTS-14 or equivalent data systems by modifying reference signals into a Digilab compatible status and clock signal. The most obvious application is to record the interferometer sync. and signal information on adjacent tracks of a tape recorder and playback the results into the Playback Console. Since signal bandwidths and gains vary in accordance with the measurements, the Playback Console has maximum flexibility inherently provided. Other features include remote selection of a particular interferogram or interferograms, monitoring at all signals on front panel with full wave peak reading meter, and all solid state circuitry.

1.1 Power Requirements

The Model DT-512 Playback Console is designed to operate from either 105-125 or 210-250 Vac rms, 50-400 Hz and requires less than 10 watts of power. Change over from one operating voltage to the other is accomplished by rewiring the input power transformer from the parallel (115 Vac) to the series (220 Vac) connection. The actual implementation is done by removing leads marked two and three and connecting them together.

1.2 Fusing

A one quarter amp fuse, located on the front panel, in- interrupts line power to the primary winding of the power transformer.

1.3 Warm Up Period

Approximately one second assures all circuitry operating in their quiescent condition.

1.4 Temperature Range

The instrument can be operated over an environmental temperature range of 10° to 50°C without any change in performance.

1.5 Operating Procedure

Data recorded on a tape recorder is transferred to the Digilab data system via the Playback Console as follows. Connect the Playback Console input cable (drawing number C-920-42) to both the Playback Console and magnetic tape recorder. Note the input BNC's are marked signal and reference respectively. Be sure to connect these inputs to the correct outputs of the tape recorder. Connect the Playback Console Input/Output Interface cable (drawing number C-920-41) to both the Playback Console and Digilab data system.

All that remains is turning on all instrument power and using the Digilab data system exactly as it was utilized with a standard interferometer chassis and optical head.

NOTE:

The Model DT-512 Playback Console has a start and stop switch on the front panel. These commands are carried to a rear panel connector (Bendix PT07C-14-85) for remote usage. If the stop button is pushed the trigger and clock signals will be inhibited and not be carried to the front panel output connectors or to the Digilab data system. The first scan after pushing the start button (or remote level change at the rear connector) is transferred to both the Digilab data system and the front panel output jacks. This is necessary when the operator desires to select exactly a particular scan or scans at high scan rates.

The sensitivity switch should be set for maximum signal on the meter <u>but less</u> than 100% deflection. Note: The monitor switch must be in the signal out position for this measurement. The sensitivity switch is explained in more detail in the electronic description section.

To accurately monitor the signal level, an oscilloscope may be connected to the signal tack on the front panel.

The monitor jack on the front panel allows the operator to measure externally the signals presented to the meter. These signals are (going in a clockwise rotation of the knob) signal in, reference, signal out, trigger, and clock.

2.0 Electronic Circuits

Figure number 1 is a simplified Block Diagram of Block Engineering, Inc.'s "Playback Console". Its purpose is to give the first time user more sure footing before looking at the Block Engineering, Inc.'s schematic drawing number E920-39,40 The electronics circuits can be divided into seven groups: the signal channel, low pass filter, Schmitt trigger, absence detector, gates, meter circuit and power supplies.

2.1 Signal Channel

The signal channel consists of one low pass filter and one adjustable gain post amplifier. The frequency response must be consistent with the signal information. Generally, a 3 pole Bessel lowpass filter is employed with roll off beginning at 10 KHz. A five position switch adjusts the gain as follows: 2, 6.67, 20, 66.7, 200. On the concentric shaft an additional continuous 3x change in gain is provided.

2.2 Reference Low Pass Filter

A Bessel 3 pole linear phase low pass filter is employed with rolloff beginning at 10KHz. An operational amplifier is used for enhancing the performance.

2.3 Schmitt Trigger

A standard operational amplifier Schmitt trigger is used with the hysteresis centered around zero volts. The hysteresis is set for approximately .2V at 5 KHz. This now allows a sine wave input to correctly trigger T^2L logic gates.

PLAYBACK CONSOLE BLOCK DIAGRAM

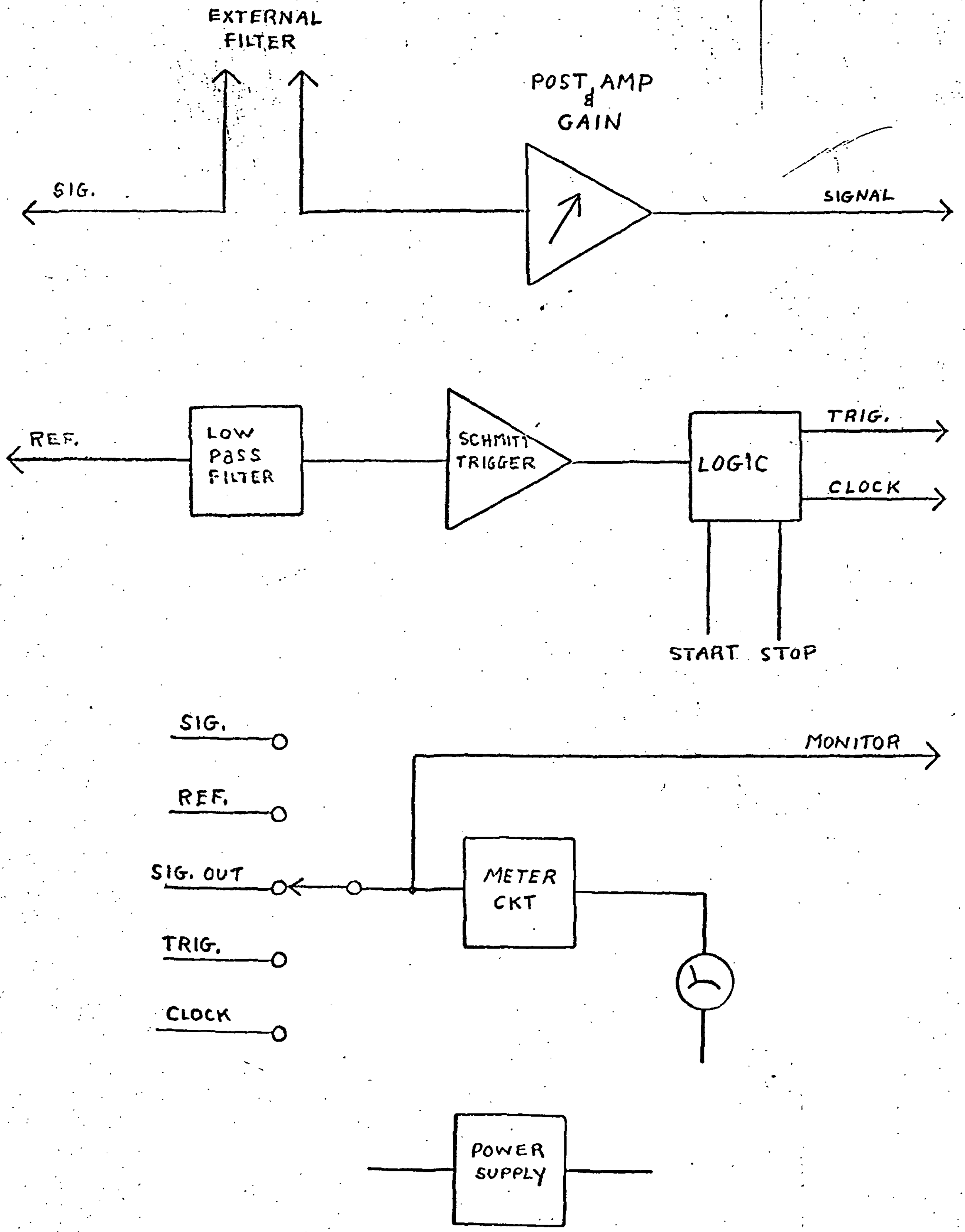


FIGURE 1

2.4 Absence

The absence detector is simply a nonretriggerable multivibrator such as the Fairchild μlogic 9601. If a second input transition occurs before the RC holdoff of the absence detector the output stays high. This allows a level to exist for a given input clock frequency, hence the trigger signal.

2.5 Gates

The gates are used to logically allow nondestructive scans by always letting a remote start or stop command to be initiated on a trigger transition. Consequently, two three input gates act as an RS flip flop to store the start or stop command. This in turn is presented to the gates through a D type edge triggered flip flop on the trigger transition. This circuitry enables you to pick a particular interferogram, especially practicle if high scan rates exist.

2.6 Meter Circuit

The meter circuit is simply a full wave peak reading amplifier. This is useful when dealing with interferograms.

2.7 Power Supplies

Input supply voltage is 115V ac rms ± 10%. The internal voltages are regulated at + 12 volts, - 12 volts and + 5 volts approximately.